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An Analysis of the Feasibility of an Automatic Vehicle Locator System for the Orlando Police Department

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AN ANALYSIS OF THE FEASIBILITY OF AN AUTOMATIC VEHICLE LOCATOR SYSTEM FOR THE ORLANDO POLICE DEPARTMENT

BY

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THESIS

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 Objective

The main goal of this thesis is to demonstrate the use of a computer simulation model to explore the effectiveness of an Automatic Vehicle Locator System in dispatching patrol cars in an urban police patrol force. The method used consists of simulation models of the present Command/Control system augmented by alternate Automatic Vehicle Locator Systems with emphasis on their dispatching disciplines. Primary effectiveness criteria were: (1) number of incorrect dispatches, and (2) response times.

The model of the present Command/Control system is first developed and shown to be a good representation of the actual system currently in use. The model was then modified to incorporate the Automatic Vehicle Locator dispatching method. Evaluation of the simulation results of the two models is then translated into operating cost saving due to the use of an Automatic Vehicle Locator.

1.2 Background

All police departments utilize some system by which they direct and control their field forces in a dynamic response environment. This system of Command and Control must have the inherent capability of rapid and complete information assembly, decision making and execution which assures rapid response to the threat situation and minimizes the danger to both citizen and police officer.

Continuous force status monitoring is one of the most effective methods of improving the Command/Control function since it provides a dynamic display which combines offense locations with deployment/availability of patrol units. Typically, continuous force status monitoring information improves command decisions which in turn improves operational efficiency of the system by:

- o reducing response time
- o dynamically deploying patrol units
- o maintaining better administrative control of patrol units

An AVL System provides the key to a quicker response because it enables the Command/Control Center to dispatch the nearest available patrol units. Also to be considered is the increased safety afforded the field officer; at all times the Command/Control Center has knowledge of his location and can respond if assistance is needed.

In addition the AVL system provides the command officers with locations of their forces during major civil disturbances or disasters. Typically the police must rely on their force mobility to extend their limited field capabilities in responding to such emergencies. The ability to concentrate on trouble spots and control them is worth many additional units in the field. Knowing the locations of patrol units also improves administrative control and avoids over or under responses that may inadvertently leave sections of the city without protection.

A number of vehicle locator systems for police operations have been conceived and some have undergone prototype evaluation. Generally, however, these have been in the larger cities such as New York, Chicago, and Philadelphia. It is evident from a review of the literature that the locator technique must be carefully selected and the system designed to satisfy not only the police operational requirements but also the physical and environmental conditions in which it must operate.

Other police simulation models, particularly the work of Larson[1], have used a purely theoretical approach in analyzing the utility of an Automatic Vehicle Locator System. Of cource, such theoretical treatment is necessary. However, models developed for real police Command/Control Systems must include parameters based on the geography of the city involved. The model developed

1 Richard C Larson, Urban Police Patrol Analysis; (Boston, Mass., The Massachusetts Institute of Technology Press, 1972), p. 183.

in this thesis uses information gathered from actual day-to-day operation of the Orlando Police Department. Data incorporated into the model includes information concerning incident rate and place of occurence as well as patrol car travel time and incident investigation time once the vehicle is at the scene. A special consideration in this model is the recognition of penalties which must be paid in travel time for a vehicle to cross over (under) large man-made obstacles, such as freeways.

2. TECHNIQUES OF SYSTEM SIMULATION

2.1 Rationale of System Simulation

The Orlando Police Department Command/Control System computer simulation model represents an abstract working model of the actual system operations, and provides an effective research tool with which to analyze the interaction of proposed organization/procedures, introduction of new technology and the operating environment.

The advantages of experimentation with a model of a real system rather than with the real system itself are: (1) the real system cannot be continually changed without jeopardizing its performance, and (2) alternate system configurations and conditions can be tried in the model which is easily modified.

The model is structured to match the basic design of the actual system and operates as a dynamic Monte-Carlo simulation by generating calls from known or postulated statistical distributions, passing these calls through each processing step a call would encounter in the real system, and by gathering data on individual system component and overall operations. As is the case with any computer model, the program does not exactly match real world system outputs, but rather serves as a close approximation to actual system operations. The long run statistical averages of model outputs and real system historical data, however, are sufficiently close to permit management to make use of model outputs in analytic and decision making application.

Proposed revisions of existing operating policies and procedures may be easily incorporated into the program logic and used to obtain predictions of overall system performance modification resulting from these changes. Similarly, the expected increase in system activity over the next several years may be simulated using the model in its present form. Alternate system designs may be simulated with the model, albeit at the expense of making revisions in the basic program logic flow; this procedure was used to incorporate an Automatic Vehicle Locator System into the Orlando Police Department operations for evaluation of its cost/effectiveness.

2.2 The System Simulation Method

The Computer Model used to describe the operation of the urban police patrol force Command/Control System provides an inexpensive, easily-used tool for describing system activity under a wide range of operating enviroments and design configurations.

Experimentation and data collection activities concerning the operation of complex man/machine systems such as a police department Command/Control Center are difficult to perform when the system must be in continuous around-the clock operation. Such studies must be designed to avoid interference with the normal operation of the system, and at the same time, provide a detailed picture of the system internal operation to be of any value to the analyst.

One approach for systems studies which has been receiving considerable attention recently relates to the computer-based simulation of these systems. "Simulation", according to one popular interpretation, is the art of predicting reality from an abstract model of reality formulated by an analyst. The system may be thought of in an engineering sense as a "Black Box" which transforms, or converts, a set of inputs into a set of outputs. The system operation is often constrained by outside restrictions, such as legal aspects, economic conditions, and possibly even humanitarian and moral considerations. The managers and workers in an organization may be thought of as generating additional control inputs within the system structure to further influence the transformation process.

The Police Department Command/Control Center operation may be readily related to the "Black Box" system operation. Citizen requests for assistance and information comprise the majority of the inputs to the system. The system, defined as the Command/Control Center and its on-duty personnel together with the

Uniformed Field Forces, transform these calls into field unit assignments for further investigation and action when deemed appropriate, resulting in outputs representing completed tasks. Constraints acting on the system are primarily those relating to legal procedural rules and physical equipment limitations, e.g., radio system capabilities and patrol unit availabilities.

A computer simulation model, then, represents a working system by imitating the "Black Box" representation of the system. The basic system description is supplied to the computer in the form of a set of instructions. Also required are the known limitation on the system performance capabilities, e.g., the number of available telephone lines for receiving input calls. The computer program is then given representative inputs and asked to predict the related outputs that the real world equivalent system would generate under the same conditions. The actual computer outputs are tested for validity and the model is changed or expanded until these outputs reach the desired degree of correspondence with their real world counterparts.

The advantages of experimentation with a model of a real system rather than with the system itself are several: (1) the real system is not disturbed by data collection activities, (2) proposed changes in the system are easily tested by changing a few computer cards in the model, (3) the modeling approach is both faster and less expensive than actual field work for the reasons cited above.

3. MODEL DESCRIPTION

3.1 Computer Program Logic

The IBM General Purpose Simulation System/360 (GPSS/360) Program was used to develop and exercise a comprehensive computer model of the Orlando Police Department Command/Control System.

The criteria used for the selection of an appropriate computer language to be used for a given simulation model involve several interlocking considerations. Perhaps the foremost of these is the inherent suitability of the language for implementation of the particular set of operating data and structural information available for the system under study. In the case of the Orlando Police Department Command/Control System project, a detailed flow chart of the operating procedures had been developed previously to support the computer work. In addition, statistical data in the form of means, standard deviations, and graphical distributions had been developed for the various times associated with the operation of the Command/Control system. These two factors suggested the use of a block-oriented simulation language to minimize the programming effort required to achieve a working model.

Such a language was available in the IBM GPSS/360 and this system was used for all subsequent computer runs on this project. GPSS/360 is one of the so-called user-oriented languages. With this program, many of the internal operations are transparent to the user of the language, and the analyst can construct a simulation model simply by selecting one language element, or command, for each block in the flow chart of the real world system.

The flow diagram shown in Figure 1 represents an overview of the basic simulation logic which is presented in more detail in subsequent sections. The block sequence along the left of the diagram represents activities in the servicing of a typical call through the actual Command/Control System. Calls arrive at the system according to some pattern depending on such factors as the time of day, the present level of criminal activity in the community, the weather, etc. Complaint Desk clerks answer the phones, gather the information as to the location and severity of the incident being reported, and as necessary, generate the appropriate Orlando Police Department forms for subsequent Radio Operator use. Information-only requests and other calls not requiring field unit attention are not documented on a form. A conveyor transports the completed forms to the Radio Operator who in turn contacts the appropriate field unit to service the call by consulting the duty roster and field unit assignment map board. The field unit assigned to a particular call must then travel to the location of the request and perform any necessary investigative and action services. When this processing is completed, the calls are removed from the system by the Radio Operator.

The corresponding system operation in the computer model is accomplished by the use of program devices called "transactions". The logic flow of the computer model is shown on the right of Figure 1, parallel to the actual System operations. These may be thought of as individual calls passing through the system. The computer uses statistical call arrival information from the real system to produce service requests at random intervals from the "generate" command. The resulting transactions pass through the remainder of the model just as the service calls would pass through the actual system, e.g., when a transaction passes through the Complaint Desk officer, it encounters a time delay determined by statistical sampling of the time delays encountered by real-world service calls at the Complaint Desk. This correspondence of model/system activity is maintained throughout the simulation process, and thus allows statistical data collected from the actual system to be used to predict the behavior of the

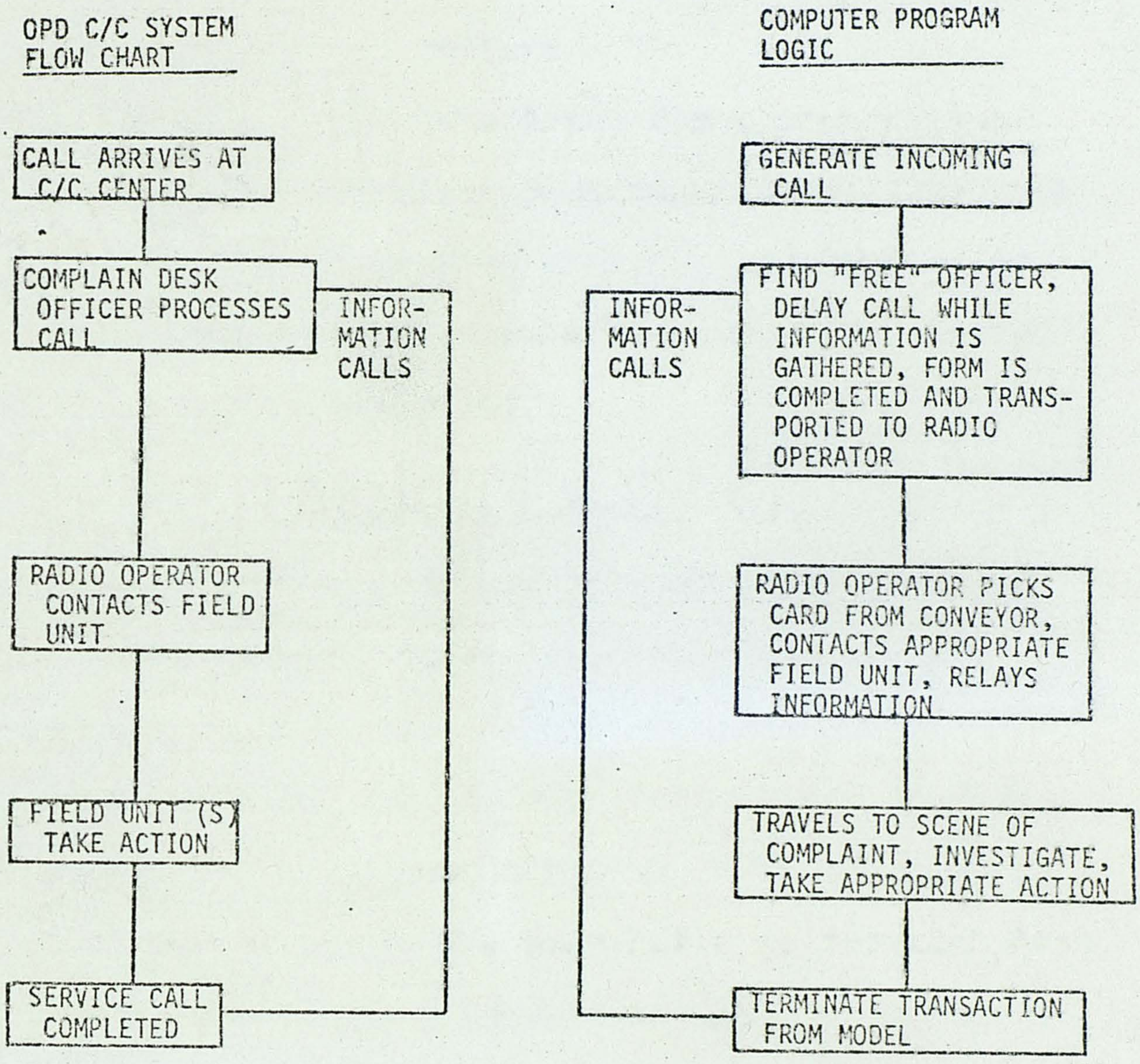


FIGURE 1 EQUIVALENCE OF GPSS/360 PROGRAM LOGIC BLOCKS TO FLOW CHART OF ACTUAL SYSTEM.

simulation model. GPSS/360 generates statistics describing the performance of structural components of the model based on actual data. A typical statistic would be the percentage of time during an eight-hour shift that a unit was "busy".

3.2 Input Data and Assumptions

The computer model data input for system action times for the Orlando Police Department Command/Control System was based on extensive statistical sampling of the actual system operation on a 24 hour basis for two six-week periods in early 1972.

The construction of the computer simulation model used in the project required essentially two types of data about the Command/Control System. The first of these categories was fixed structural data on the configuration of the system, e.g., the number of Radio Operator and Complaint Desk stations to be considered for each simulation run; or, somewhat more detailed data, such as which radio channels were assigned to which field units. This data was typically obtained from physical plans of the Command/Control Center and from discussions with Command/Control Center personnel and supervisors. The second major category of data was that relating to operational characteristics of the system. This classification included such factors as the determination of times for the human operator actions required to service an incoming call requesting police action. It is instructive at this point to consider how a representative data item was obtained from the actual system operation and transformed into a form suitable for the computer model.

Consider the problem of generating service request calls to the System which simulates the actual calls seen at the Command/Control Center. The timing of the intervals between the arrival of successive calls over a long period of time allows the specification of a statistical interarrival time distribution for these times. This distribution can be entered into the computer simulation program in the form of a table of numbers, called a "FUNCTION" in GPSS/360. This procedure, outlined in the table on the facing page, requires an intermediate step consisting of the preparation of a cumulative statistical distribution on the time variable involved. The cumulative distribution gives the probability that the particular time element in question is less than or equal to some stated value. This distribution is then converted to a sequence of (x,y) data points and punched onto computer cards in the format representing a GPSS/360 "FUNCTION" statement. The name "SHIFT1" is a symbolic name assigned to the data curve in the function and whenever this name is referenced in the computer model, this curve will be selected for processing. When in operation, the simulation program selects a random number from one of the built-in generators, and addresses the SHIFT1 function to obtain the next call's interarrival time. This value is added to the master simulation clock time to determine the time at which the next outside call will enter the Command/Control System.

All of the Command/Control Center operational time elements were entered into the model in the manner described above, resulting in a total of some 17 time functions in the final model. The standard caution directive that "a computer model is only as good as its input data" was noted throughout the data collection and preparation process; every attempt was made to include only valid data values.

3.3 Data Validation by Statistical Hypothesis Testing

The data on simulation parameters was subjected to Statistical Hypothesis Testing utilizing the Student-t distribution in order to establish at what level a statistical difference existed among the parameters by day of week and duty watch.

Prior to use as input to the simulation model, the data on each parameter describing the Command/Control System process was statistically tested to establish its degree of validity. Specifically, the sample mean for each parameter was required to approximate the population mean within a specified tolerance to be acceptable.

Typically, statistical hypothesis testing is a methodology comprised of a number of carefully defined steps; formulating the null and the alternative hypothesis, specifying the level of significance, selecting the testing statistic, establishing decision criteria, doing computations and making decisions.[1]

To formulate the null and alternative hypothesis, the mean of the sample means $\bar{\bar{x}}$ was used as the population mean μ. The basic question was whether there existed any significant difference from this mean and the other means by day and by shift for each of the simulation parameters. Since $\bar{x}$ may be greater or smaller then $\bar{\bar{x}}_T$, a two-tailed testing procedure is indicated. The null and alternative hypothesis can be expressed,

$$H_o: \quad \bar{x} = \bar{\bar{x}}$$

$$H_1: \quad \bar{x} \neq \bar{\bar{x}}.$$

A confidence level of 90% was used to be consistant with the confidence level used in determining sampling size. Two types of errors are possible in hypothesis testing.

1 Ya-Lun Chou, Statistical Analysis with Business and Economic Applications (New York, N.Y.: Holt, Rinehart, Winston, Inc. 1969), p. 313.

The 90% confidence level is an indication of an α or type I error, that is, 10% of the time, rejection of the null hypothesis will be made when it should have been accepted. The second type of error is termed β or type II error. This is committed when the null hypothesis is accepted when it should have been rejected. The error is a measure of the power of the test statistic.[2]

The selected testing statistic utilized the Student-t distribution because the small sample size (n = 7) does not support the normal "Z" test statistic and because the population variance was unknown. The degree of freedom for the test will be n - 2 = 5. Two degrees of freedom are lost because the population parameters μ and σ were approximated by $\bar{\bar{x}}$ and $S_{\bar{\bar{x}}}$. To establish the decision criteria the following theorem was utilized:

> "If $\bar{\bar{x}}$ is a mean of a random sample size n taken from a normal population bearing a mean μ and the variance σ^2, then $t = \frac{\bar{x} - \mu}{s/\sqrt{n}}$, is the value of a random variable having the Student-t distribution with the parameter $\nu = n - 1$."[3]

The corresponding t value for $\nu = 5$ and $\alpha = .05$ is 2.015.

2 Irwin Miller and John E. Freund, Probability and Statistics for Engineers (Englewood Cliff, N.J.: Prentice Hall, 1965), p. 153.

3 Ibid., p. 136.

The decision criteria is, accept H_o if $\left| t_{-x} \right| < 2.015$ and reject H_o if $\left| t_{-x} \right| > 2.015$.[4]

3.4 Assumed Dispatching Disciplines

To operate the computer simulation model, a decision logic must be defined for the assignment of patrol units to an incoming call, to introduce a decision structure into the simulated operations.

The Orlando Police Department operates four major classifications of patrol units: individual cars operated by patrolmen, individual cars operated by Sergeants, individual cars operated by Lieutenants, and motorcycle units, which are principally assigned to traffic duty. Cars operated by Sergeants and Lieutenants are generally assumed to be supervisory but these units do respond to incident calls under certain conditions. The rules applied in the computer model are discussed below under the major operating categories of the computer model. In the "present system" the decision rules correspond approximately to the current methods in use at Orlando Police Department. Under the Automatic Vehicle Locator System (AVL System) the postulated assignment discipline is described. Although this is a future system, the rules applied are deemed to be

4 *Ibid.*, p. 399.

reasonable and close to expected operating procedures.

Existing Assignment by District: When an incident occurs, an attempt is made to dispatch a car in the district in which the incident has occurred. If no unit is available in that district, then the district north (south) of the incident district is searched for a free unit. If no unit is available in those districts, then the district east (west) of the incident district is searched for a unit to be dispatched. If no available unit is located through this 360° search, the Sergeant and motorcycle units are searched for dispatch. If no unit is located among these resources, the call is essentially unanswered and is inserted into a queue for accomplishment when an unassigned unit is available. On high priority calls in a queue situation, the higher priority (emergency) incident bumps lower priority incidents into the queue. Examples of district search are shown in Figure 2. For incident 1 (in District 2) District 2 is searched first followed by a search of Districts 4, 1, and 3 respectively. Similarly, for incident 2 (in District 4) the order of search is Districts 4, 2, 3, and 1 respectively. Similarly for incidents 3 and 4 the order of search is (1,3,2,4) and (3,1,4,2).

Automatic Vehicle Locator (AVL) System: Dispatch

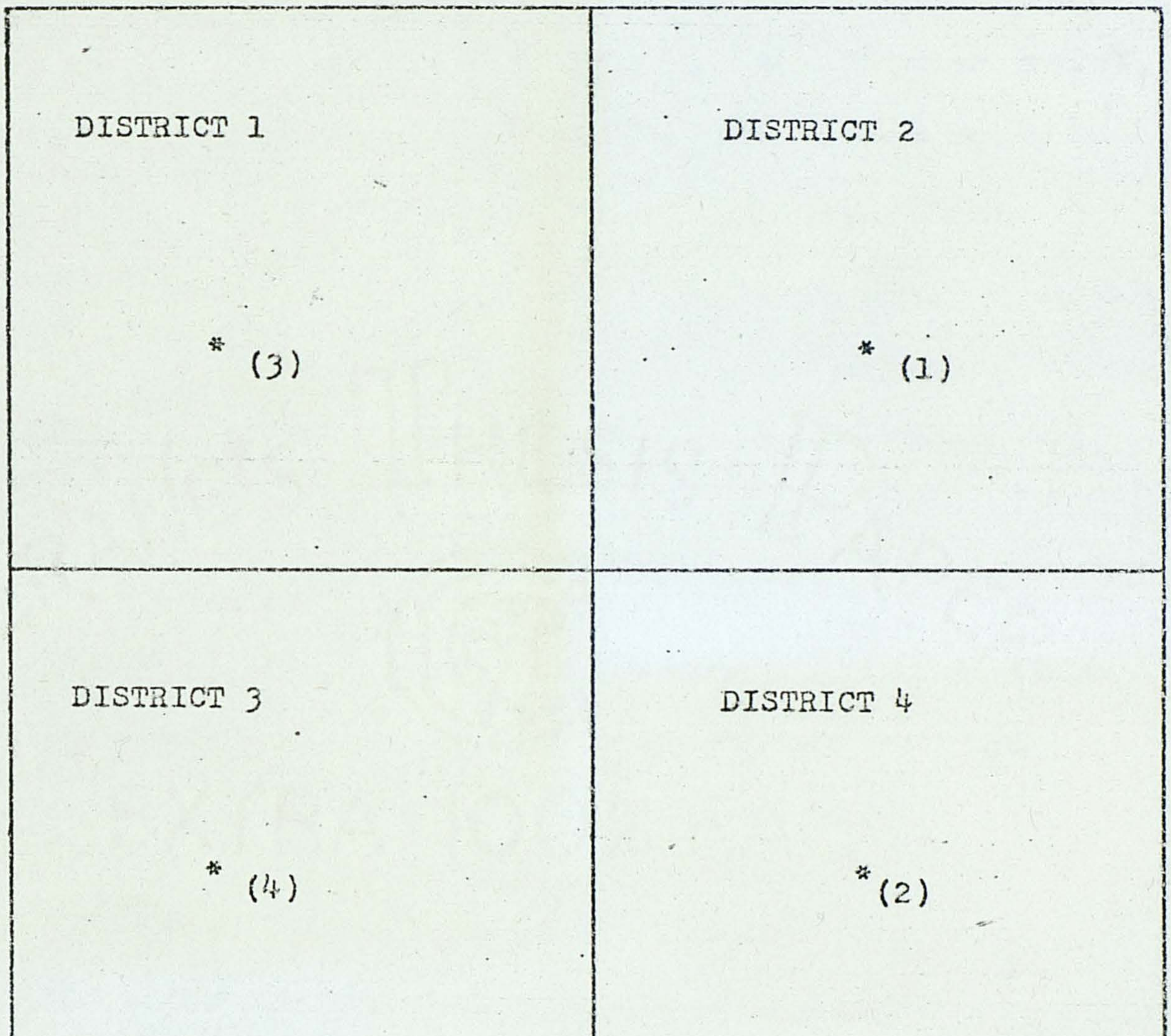


FIGURE 2 EXAMPLE OF DISPATCHING ROUTINE FOR EXISTING (NON-AVL) SYSTEM.

decisions in a system using AVL are made by computing actual distance from an incident scene to available field units. The closest available field unit is assigned (exclusive of Lieutenants and Motorcycles). If a unit manned by a patrolman is not available, the closest Lieutenant or Motorcycle is dispatched. As with the present system, if no available units are found the call is placed in a queue to await the first available unit. In calculating distances in the computer model, the operating area is overlaid with a system of grid lines providing coordinates of any point. These coordinates, then, are used to determine the rectangular distance (as with city streets) between any two points of interest. Distances computed in this manner become highly important in experimentation with the simulation model. Since locations and distances are known exactly, the influence of accuracies of various AVL systems can be evaluated in terms of incorrect dispatches and additional unnecessary distance travelled.

3.5 Output Information

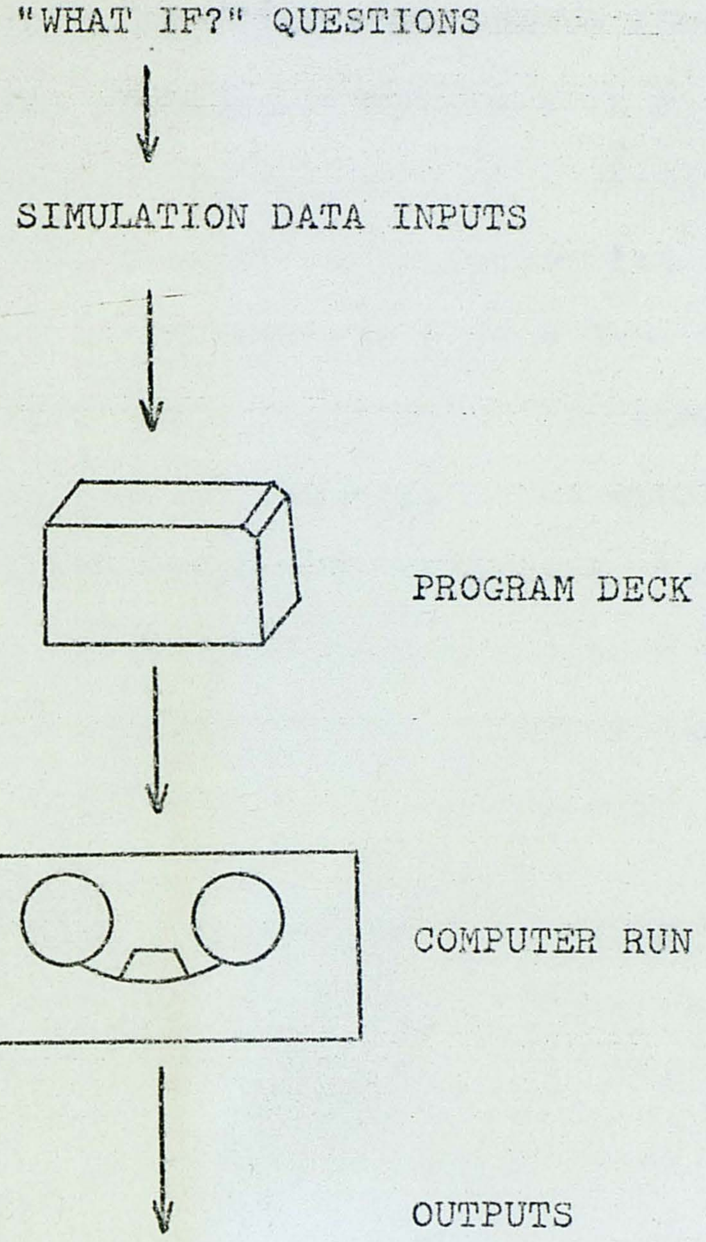
The output information from the computer simulation model may be used for two major steps of the system study process: model validation, and evaluating proposed system design changes under varied operational and environmental conditions. In the first phase, model outputs such as those depicted in Figure 3 were compared with known system performance data for standard and non-standard operating conditions. The model was then refined through data resolution changes or structural modifications to bring its outputs within an acceptable correspondence to those of the real world system. In GPSS/360 modeling, this process of model "tuning" typically occupies a significant portion of the total model preparation time. As with any Monte-Carlo simulation procedure, GPSS/360 is sensitive to the various values selected as initial conditions on the random number generators providing the dynamic stochastic behavior of the model. For this reason, several runs with different initial random number values were made for each proposed system design or data change to assure that the range of model variation due to this condition was adequately represented.

The various model outputs are used in both design and analysis applications once the model has been validated. For example, in the case where the feasibility of an Automatic Vehicle Locator (AVL) is under study, the statistical properties of field unit 10-6 time (time for a unit to reach an incident scene after dispatch) are obtained from several computer runs. These data provide a measure of system response to permit a comparison of AVL and the existing distinct dispatching system. In this study, two principle areas of comparison are under consideration; the economy of an AVL system versus present system, and effects of varying accuracies of the AVL system. Toward the first objective, the simulation model is modified to increase the number of operating units to a point of equivalence of system response between AVL and non-AVL operations. The number of additonal cars required to achieve this equivalence is seen as a measure of the economic contribution of an AVL system. Similarly, the effects of varying AVL accuracies can be studied by examining model outputs while stepping through several AVL accuracy levels. The overall simulation process is portrayed in Figure 3, showing the flow of effort beginning with a "what if" question leading to the broad range of possible model outputs. These outputs are futher discussed in later sections of this report.

3.6 Validation of Simulation Model

Comparison of the computer model outputs with corresponding parameters from the real world Orlando Police Department Command/Control System was the primary validation mode used for the simulation model of the present dispatching method.

The concept of the validation of a computer simulation model is often stated in absolute terms,



FACILITY UTILIZATION	NUMBER OF TYPE OF CALLS GENERATED	SYSTEM RESPONSE TIMINGS
o RADIO OPERATORS	o DISTRICTS WHERE ORIGINATED	o 10-6 DISTRIBUTION
o FIELD UNITS		o 10-8 DISTRIBUTION

FIGURE 3 RANGE OF OUTPUTS GENERATED BY GPSS/360 SIMULATION MODEL OF ORLANDO POLICE DEPARTMENT COMMAND/CONTROL SYSTEM MODIFIED FOR EVALUATION OF AVL SYSTEMS.

although a more realistic approach may involve working towards relative states of model agreement with reality. One reference[5] has defined the validity of a simulation model as "...the extent to which it satisfies its design objectives." The goal of the Orlando Police Department Command/Control System model was not to obtain exact duplication of real system performance, which would be impossible to achieve, but rather to achieve a reasonable approximation of real system performance and produce a model that would yield useful information about the system's operations. This goal has been achieved.

There are three basic approaches to assuring model validity;[6] all were employed in the construction of the Command/Control System Model to some extent. The first approach required building realism into the model structure, and typically involved making detailed analyses of actual system operating procedures and translating these into model language statements on a "one to one" basis. Representative coding from the model structure for the complaint desk personnel activity and the field unit operations is included elsewhere in this report. The model statements, in general, have a direct relationship to know actions

5 Herbert Mainsell and Giuliano Gnugnoli, Simulation of Discrete Stochastic Systems, (Chicago, Illinois: Science Research Associates, 1972), p. 33.

6 Op. Cit., pp. 33 - 35.

in the real world on an elemental basis, which is the rationale for declaring that exact agreement between the model outputs and the actual system operations is extremely unlikely. For example, incident investigation time is modelled by a GPSS/360 language statement of the form "ADVANCE FN$INV03". This has the effect of causing the simulator to pick a random number internally and use its value to obtain an investigation time value for the unit from the data function named "INV03". This time function was derived from statistical sampling of actual Orlando Police Department investigation times. While the simulation model will not exactly match actual Orlando Police Department statistical behavior, on the average investigation time in the model will correspond to real-world investigation time. This result is, in fact, the theoretical basis for Monte Carlo system simulation, e.g., the statistical description of a system operating characteristics may be obtained from the aggregation of a member of samples from the system expected operating regimes.

The second validation approach involves assessing the reaction of knowledgeable personnel to the model outputs for familiar operating conditions. This action may be helpful in isolating and identifying doubtful results in the model outputs.[7] This comparison was done for the project simulation model and yielded the extremely important information that predicted Radio Operator "busy time" statistics were uniformly too low to represent a reasonable cut at reality. This discrepancy was investigated, and found to be due to the omission of certain types of background radio message traffic, e.g., detective unit calls and accident investigation car reports. The accurate simulation of the full Radio Operator's task spectrum in the completed model was thus found to require additional statistical sampling of these necessary events.

The third approach to validation relates to formal comparison of simulation model outputs to reference data which may be available for the system being studied. This reference data is typically historical data on system operations under known conditions in the past. Again the exact correspondence of Model/System output is not required or sought, but rather the objective is to achieve a degree of correspondence satisfying the need of the study.

3.7 Statistics of Validation

"An empiricist is one who believes only what his

7 Op. Cit., p. 35.

senses tell him; in this case he has made an outrageous leap into the unknown."[8]

The question of the relationship between the problems of validation and inference arising from simulations of human systems is challenging. Validation, as mentioned earlier, relates to the degree of "realism" associated with a model, whereas inference, or the methodology of drawing conclusions from data, often requires consideration of the "formalism" associated with a simulation process.[9] The statistical procedures for initial model validation require the analyst to carefully consider these somewhat mutually conflicting concepts. Consider the accompanying chart, taken from Phaff and Phaff[10], and representing the range of simulations of human behavior. The Orlando Police Department Command/Control System model would fall somewhere near the "complex all computer experiment" region of the chart, the primary classification criteria is the relative degree of variable interactions that

8 C.W. Churchman, "An Analysis of the Concept of Simulation" Symposium on Simulation Models: Methodology and Applications to the Behavioral Sciences (Cincinnati, Ohio Southwestern Publishing Co., 1969) pp. 1-2.

9 Martin Phaff and Anita Phaff, "Statistical Analysis of Simulations of Human Systems": Proceedings of Eighth Symposium of the National Gaming Council, Excelsior Springs, Mo., June, 1969, p.2.

10 Op. Cit. p.7.

exist within the model structure. The primary effect of this classification is that variable responses in the model are not independent in nature, and therefore cannot be treated with classical experimental design techniques. Analysis of such models typically then depends on single runs or replications to obtain descriptive model behavioral patterns.

One additional theoretical concept should be addressed with respect to statistical validation of model behavior. This concept is that if a model describes some hypothetical or proposed system, no validation can in fact, be accomplished. This is a natural consequence of the fact that "... if no numerical data exists for an actual system, it is not possible to establish the quantitative congruence of a model with reality."[11] The importance of this fact in the present study is that the output data relating to the future Command/Control systems considered as alternate designs to the present system will have this characteristic.

To illustrate the statistical testing typical of that which can be done to validate the model, the analysis of model behavior for field unit travel time

11 G.S. Fishman and P.J. Kiviat, "The Statistics of Discrete Event Simulation", Simulation, April, 1968, pp. 191.

data will be presented. Manual sampling over several weeks with the actual system produced a mean of 4.605 minutes for this data element. The computer model yielded a mean value of 4.14 minutes and a standard deviation of 2.918 minutes for this same variable over a series of 3 model runs under the current implementation system. Additional data collection items were not made at this point in the study for this case, as each run was costing approsimately $21.00 for computer time and additional development work requiring considerable expenditures was being projected for the model. The applicable statistical test was conducted as follows:

Null Hypothesis: $\bar{x} = \bar{\bar{x}}$

Test Statistic: $t = \dfrac{4.14 - 4.605}{2.918/\sqrt{3}} = -.275$

Rejection Region: For $\alpha = .05$, reject for $t > 2.920$

Conclusion: Accept the Null Hypothesis

4. SIMULATION RESULTS

4.1 The simulation study compared the effects of AVL accuracies in two important areas: the number of incorrect dispatches and the average distance travelled due to an incorrect dispatch.

The simulation model of the Automatic Vehicle Locator System was run with accuracies of ± 0 feet, ± 500 and ± 1000 feet. Four runs of the model were made with each run processing 500 incidents. In order to insure steady state conditions, 1000 incidents were processed through the model prior to collecting performance statistics. It is well known that transient effects in a simulation model must be eliminated to permit reliable results from the model. As a further control on variability between runs, each set of four runs was averaged to obtain the results shown on page 33.

The first graph, Figure 4 shows the average extra distance traveled by an incorrectly dispatched unit as approximately 0.4 mile with an AVL of ± 500 foot accuracy. An incorrectly dispatched unit is defined as a unit which is not the physically closest available

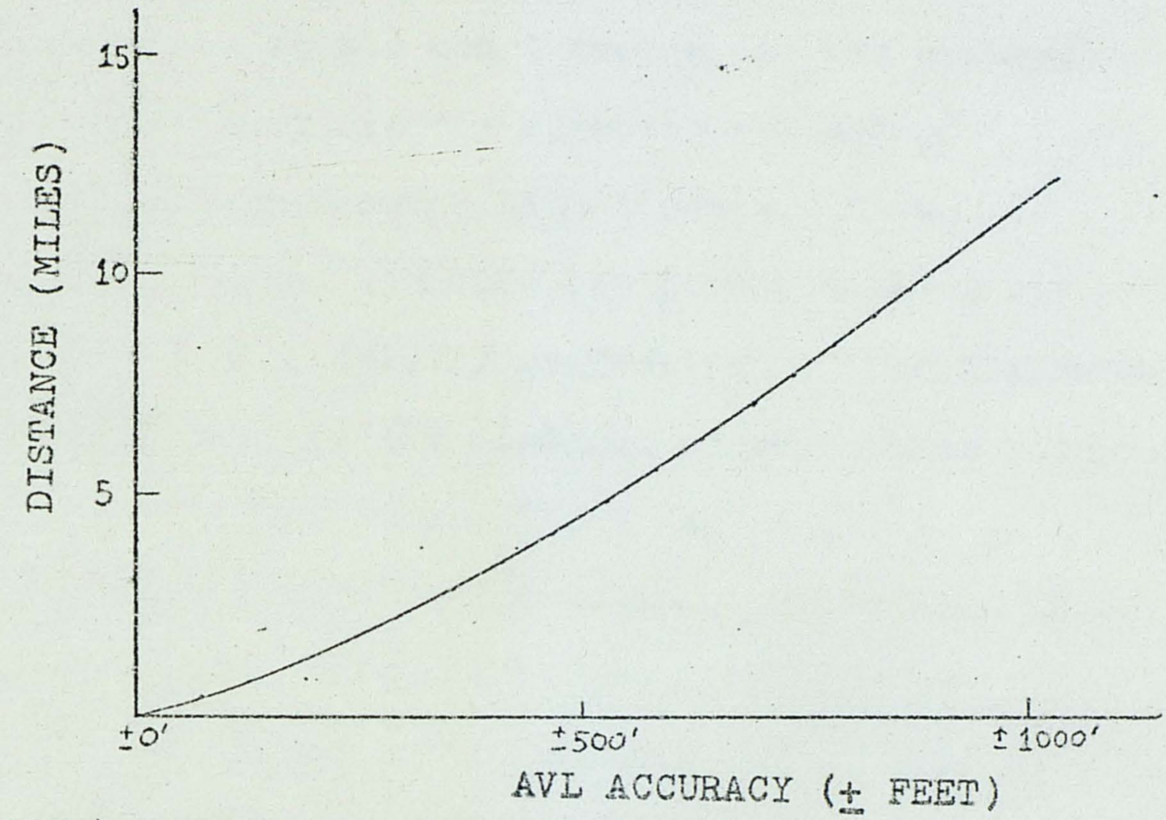


FIGURE 4 AVERAGE DISTANCE TRAVELED DUE TO WRONG DISPATCH.

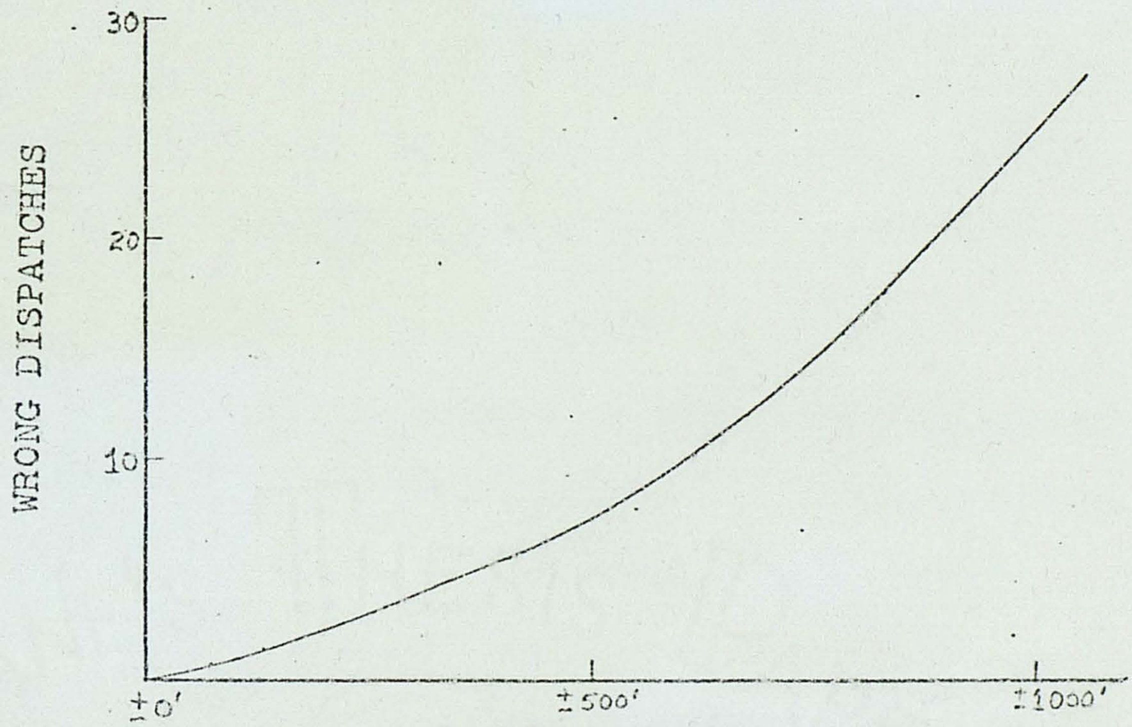


FIGURE 5 NUMBER OF WRONG DISPATCHES

unit to the incident under process. Physical distance in the model is measured in horizontal and vertical (X,Y) distances. In the model design, it was assumed that X,Y travel most closely approximated actual travel of a vehicle through city streets. As an illustrative example, consider two points A and B with coordinates (X1,Y1), (X2,Y2) respectively. The following simple formula relates the distance between these points:

$$\text{Distance} = |X_1 - X_2| + |Y_1 - Y_2|$$

where the vertical bars designate absolute value. In Figure 4, distances measured by this formula for incorrectly dispatched units averaged approximately one mile for the AVL System with ± 1000 foot accuracy. It will be noted that the distance travelled increases sharply with decreasing AVL System accuracy. Computer runs with ± 50 foot accuracy showed little difference from ± 0 foot accuracy but distance increases rapidly as accuracy is degraded to the ± 500 and ± 1000 foot levels.

For each of the accuracies in Figure 5, the number of incorrect dispatches increases as the accuracy of the AVL System is decreased. An incorrect dispatch is defined as the selection of a unit for assignment which is not physically closest to the incident scene. The selection of this parameter relates to the assumption that incorrect dispatches obviously degrade overall system response time. In the second figure, the number of incorrect dispatches almost doubles as the accuracy goes from ± 500 feet to ± 1000 feet, increasing from 17 wrong dispatches at the ± 500 feet accuracy to 30 for the ± 1000 feet accuracy system. The parameters of wrong dispatches and average distances travelled due to wrong dispatches have been determined by Larson[1] as significantly important measures of system performance.

1 Richard C. Larson, Urban Police Patrol Analysis, (Boston, Massachusetts, The Massachusetts Institute of Technology Press, 1972), p. 183.

5. CONCLUSIONS

The computer simulation model was developed to permit an assessment of the value of an Automatic Vehicle Locator (AVL) System and the influence of the accuracy of such a system.

The two systems under comparison are the existing district dispatching system (without Automatic Vehicle Locator) and the proposed closest vehicle dispatch using automatic vehicle locators of varying accuracy. Comparison of the two systems is based primarily on the tabulated values of 10-6 time (time from receipt of call until a unit arrives at the scene of the incident) and impact of dispatching the incorrect patrol vehicle. The Automatic Vehicle Locator System model was run to obtain results for three different accuracies $\pm$ 0 feet, $\pm$ 500 feet, and $\pm$ 1000 feet.

To interpret the system behavior under various accuracies, a means of comparison to the present system was needed. For the purposes of this study, it was deemed appropriate to increase the number of units in the present system to a point where both systems were equivalent in response time. Thus if the AVL System response time were less than the existing District Dispatching System, more patrol vehicles would be added until the existing system obtained the same reduction in response time.

Under this procedure, the model of the present system was run with the same number of vehicles (34) as assumed in the Automatic Vehicle Locator System. More vehicles were added, one at a time, to the model of the present system. The simulation was run again and the results noted. This was carried out repeatedly until the 10-6 time equalled or was less than, the 10-6 time of the Automatic Vehicle Locator System. As vehicles were added to the present system, they were placed in districts showing the most activity in the previous run.

A graphic comparison of the two systems is shown in Figure 6. Some of the results shown by the graph include:

1. A perfect Automatic Vehicle Locator System will operate as well as the present system with 37 vehicle.
2. A 500 foot accuracy Automatic Vehicle Locator System has the performance of the present system using 36 vehicles.
3. The two systems are approximately equal with an

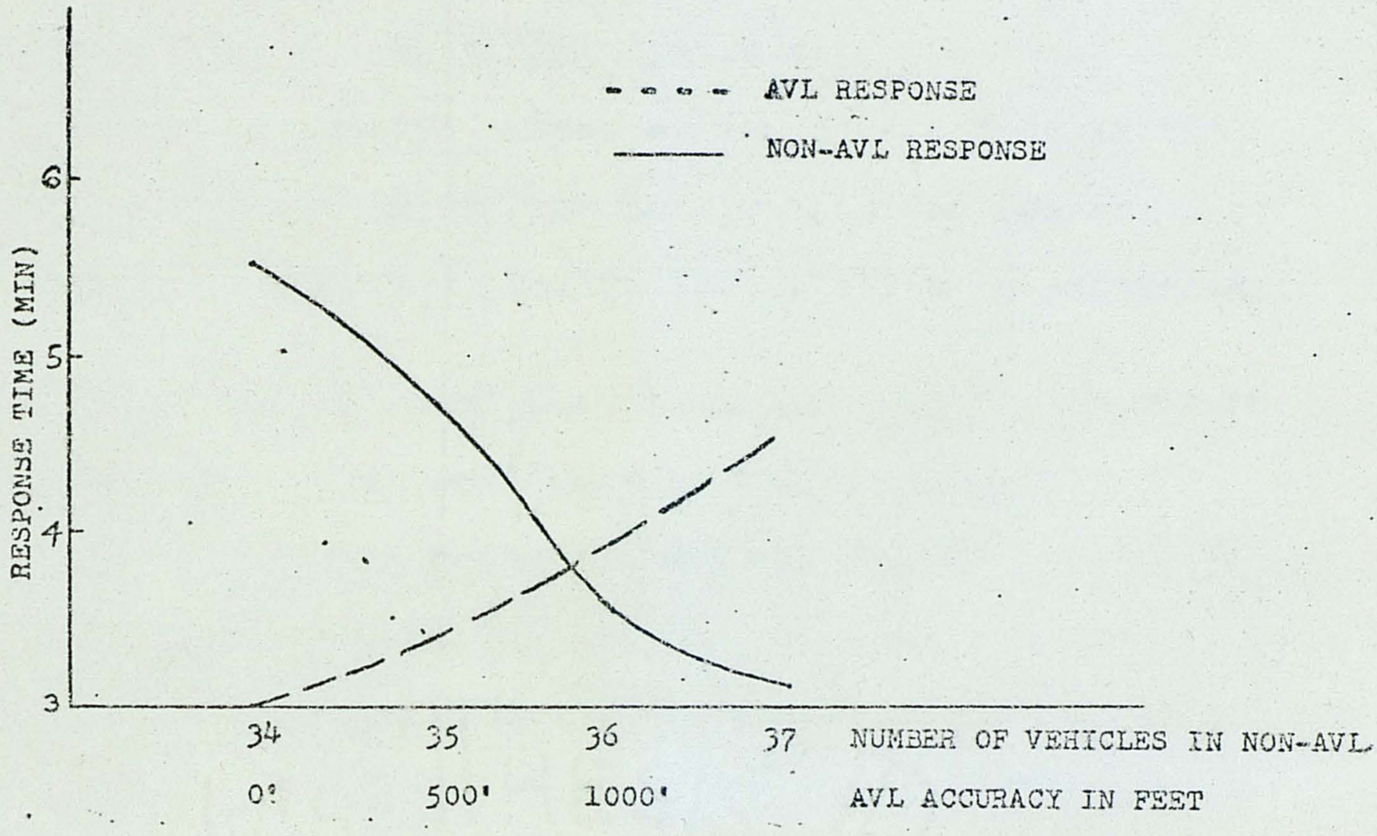


FIGURE 6 GRAPHICAL COMPARISON OF NON-AVL UNIT COUNT VS. AVL ACCURACY.

Automatic Vehicle Locator System of 900 feet and the present system with 35.8 vehicles.

On an overall basis, we may conclude that the cost of operating 1.8 vehicles (rounded off to 2 vehicles) may be compared with an AVL system with 900 feet accuracy. In general, then, we may assume that if the 900 feet AVL System is less costly then the operation of 2 additional patrol units its installation is justified.

It should be noted that there are several points of departure for additional work on the simulation of vehicle dispatching methods. One of the problems found in this current AVL model was the peculiar characteristic which shows the system response time improving as the accuracy of the AVL exceeded $\pm$ 1500 feet. This problem apparently stems from the geometry of the police districts used and was not investigated further. Another problem deserving of consideration is the matter of repositioning a vehicle back to its own patrol area in a way such that it might service a call before returning to its district. This matter was not considered in the present model. General problems to be considered in a model of the type described in this thesis are, (1) the steady-state condition must be realized before statistics gathering is done, and (2) the programming of the model must be done in a way which allows it to be easily modified to add new parameters.

APPENDIX I

MODEL FLOWCHARTS

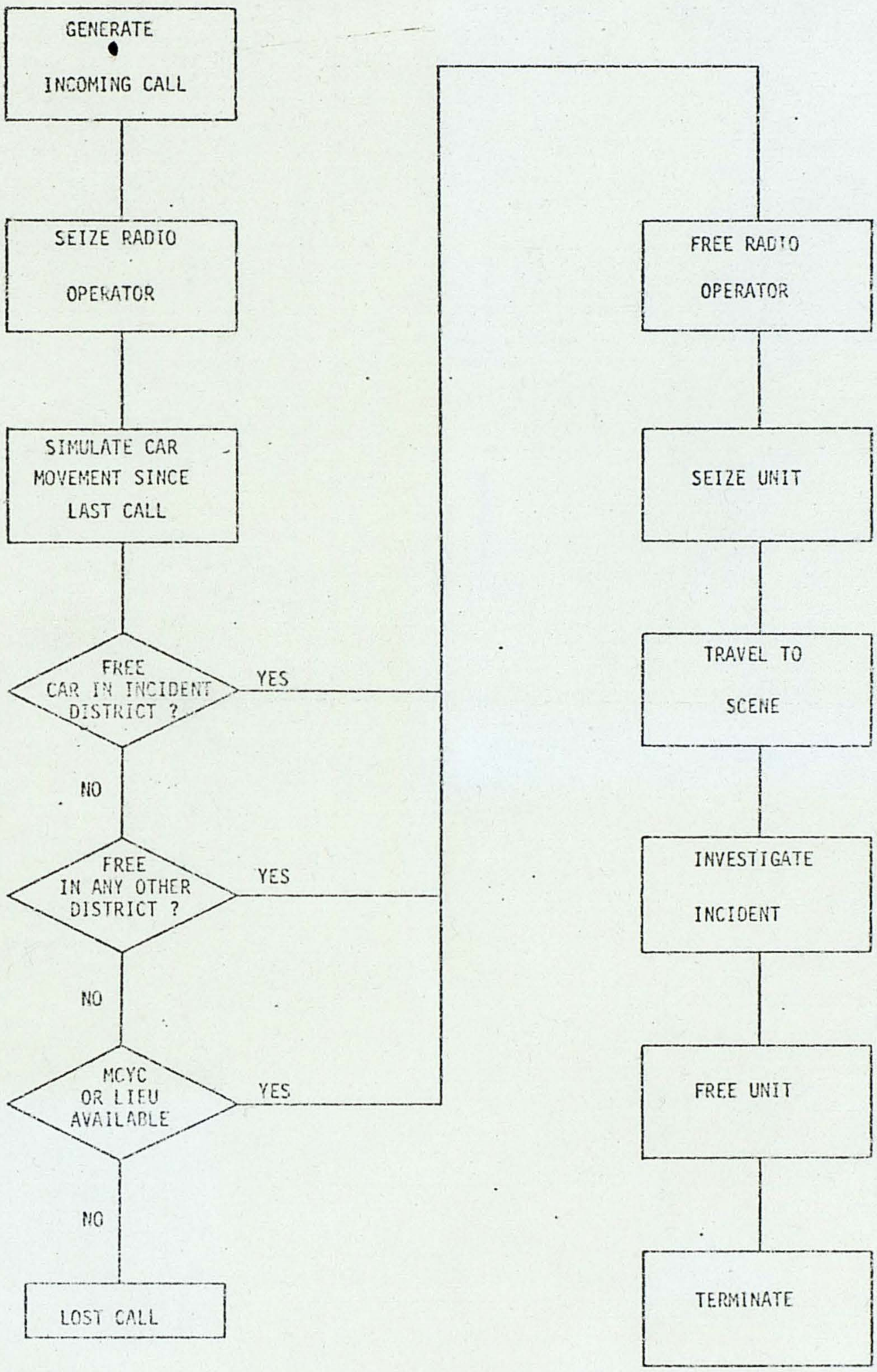


FIGURE A1 LOGIC CHART OF PRESENT (NON-AVL) SYSTEM

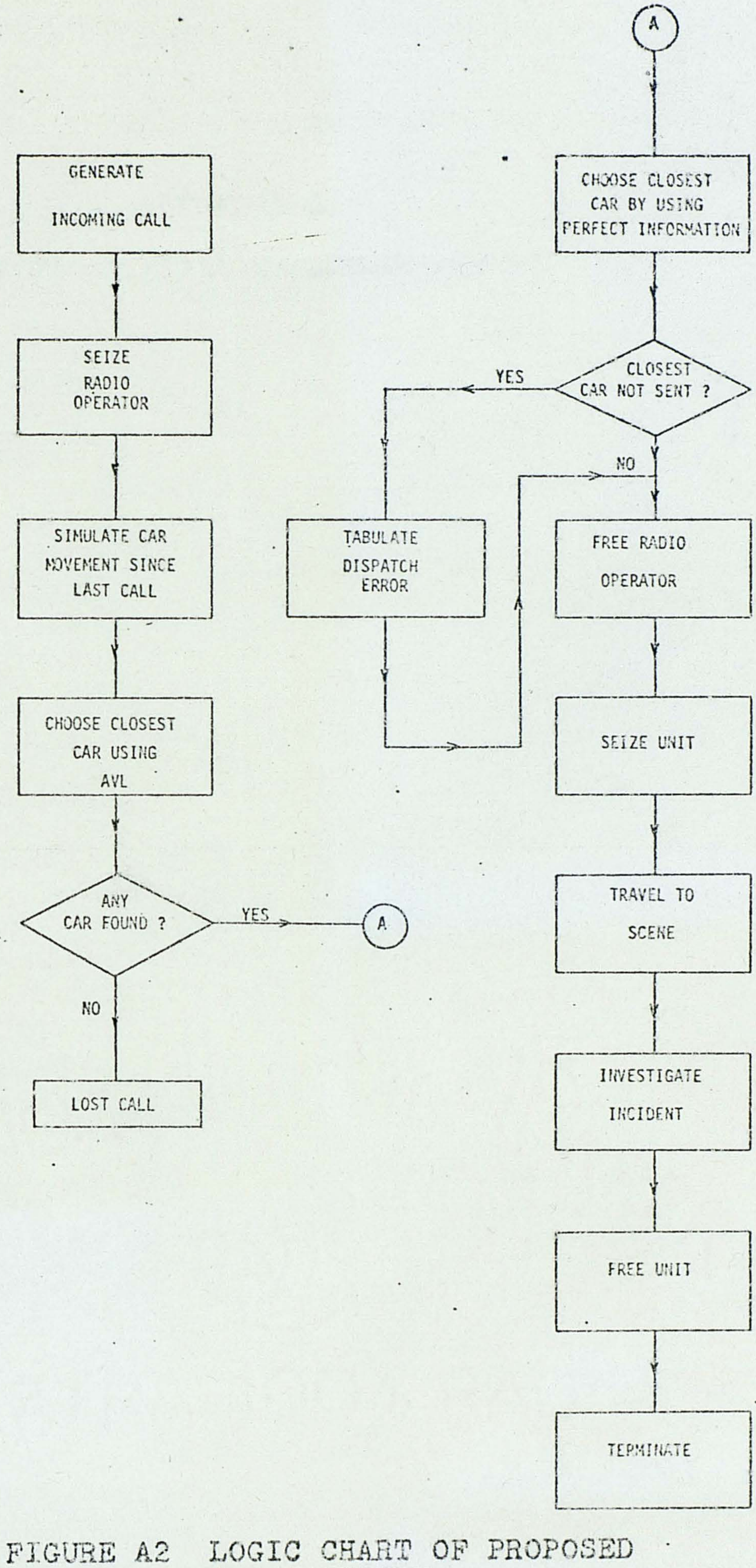


FIGURE A2 LOGIC CHART OF PROPOSED (AVL) SYSTEM.

APPENDIX II

GPSS/360 LISTING OF NON-AVL MODEL

```
BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G              COMMENTS
        *      CLOCK TIME IN 1/100 MINUTES
        *
        *
        *
        *
        *      ASSUME UNITS MOVE AT 20 MPH AVERAGE OR 1760 FEET/MIN
        *      EACH X-Y MOVEMENT IS 0-880 FEET WITH A UNIFORM DISTRIBUTION
        *      LOGIC SWITCHES 1-18 INDICATE WHETHER OR NOT A UNIT
        *      IS IN ITS ZONE.
        *
        *      LOGIC SWITCH SET - UNIT OUT OF ZONE
        *      LOGIC SWITCH RESET - UNIT IN ZONE
        *      EACH POSITION ON THE SACLE IS ASSUMED TO BE 0.01 MILE
        *      OR 528 FEET.
        *      CITY IS ASSUMED TO BE 10 MILES SQUARE.

         CAR01 EQU        1,F
         CAR02 EQU        2,F
         CAR03 EQU        3,F
         CAR04 EQU        4,F
         CAR05 EQU        5,F
         CAR06 EQU        6,F
         CAR07 EQU        7,F
         CAR08 EQU        8,F
         CAR09 EQU        9,F
         CAR10 EQU        10,F
         CAR11 EQU        11,F
         CAR12 EQU        12,F
         CAR13 EQU        13,F
         CAR14 EQU        14,F
         CAR15 EQU        15,F
         CAR16 EQU        16,F
         CAR17 EQU        17,F
         CAR18 EQU        18,F
         CAR19 EQU        19,F
         CAR20 EQU        20,F
         CAR21 EQU        21,F
         CAR22 EQU        22,F
         CAR23 EQU        23,F
         CAR24 EQU        24,F
         CAR25 EQU        25,F
         ASL1  EQU        26,F
         SARG1 EQU        27,F
         CAR26 EQU        28,F
         CAR27 EQU        29,F
         CAR28 EQU        30,F
         CAR29 EQU        31,F
         CAR30 EQU        32,F
         CAR31 EQU        33,F
         CAR32 EQU        34,F
         CAR33 EQU        35,F
         CAR34 EQU        36,F
         CAR35 EQU        37,F
         CAR36 EQU        38,F
```

```
CAR37 EQU          39,F
CAR38 EQU          40,F
CAR39 EQU          41,F
CAR40 EQU          42,F
CAR41 EQU          43,F
CAR42 EQU          44,F
CAR43 EQU          45,F
CAR44 EQU          46,F
CAR45 EQU          47,F
CAR46 EQU          48,F
CAR47 EQU          49,F
CAR48 EQU          50,F
CAR49 EQU          51,F
CAR50 EQU          52,F
ASL2  EQU          53,F
SARG2 EQU          54,F
CAR51 EQU          55,F
CAR52 EQU          56,F
CAR53 EQU          57,F
CAR54 EQU          58,F
CAR55 EQU          59,F
CAR56 EQU          60,F
CAR57 EQU          61,F
CAR58 EQU          62,F
CAR59 EQU          63,F
CAR60 EQU          64,F
CAR61 EQU          65,F
CAR62 EQU          66,F
CAR63 EQU          67,F
CAR64 EQU          68,F
CAR65 EQU          69,F
CAR66 EQU          70,F
CAR67 EQU          71,F
CAR68 EQU          72,F
CAR69 EQU          73,F
CAR70 EQU          74,F
CAR71 EQU          75,F
CAR72 EQU          76,F
CAR73 EQU          77,F
CAR74 EQU          78,F
CAR75 EQU          79,F
ASL3  EQU          80,F
SARG3 EQU          81,F
CAR76 EQU          82,F
CAR77 EQU          83,F
CAR78 EQU          84,F
CAR79 EQU          85,F
CAR80 EQU          86,F
CAR81 EQU          87,F
CAR82 EQU          88,F
CAR83 EQU          89,F
CAR84 EQU          90,F
CAR85 EQU          91,F
CAR86 EQU          92,F
CAR87 EQU          93,F
CAR88 EQU          94,F
CAR89 EQU          95,F
```

```
CAR90 EQU      96,F
CAR91 EQU      97,F
CAR92 EQU      98,F
CAR93 EQU      99,F
CAR94 EQU      100,F
CAR95 EQU      101,F
CAR96 EQU      102,F
CAR97 EQU      103,F
CAR98 EQU      104,F
CAR99 EQU      105,F
CAR00 EQU      106,F
ASL4  EQU      107,F
SARG4 EQU      108,F
LIEU  EQU      109,F
MCYC1 EQU      110,F
MCYC2 EQU      111,F
MCYC3 EQU      112,F
MCYC4 EQU      113,F
MCYC5 EQU      114,F
MCYC6 EQU      115,F
MCYC7 EQU      116,F
WEST  EQU      149,F,Q
EAST  EQU      150,F,Q

1     MATRIX   H,120,8
      INITIAL  MH1(1,1),100/MH1(1,2),199
      INITIAL  MH1(2,1),200/MH1(2,2),299
      INITIAL  MH1(3,1),300/MH1(3,2),399
      INITIAL  MH1(4,1),400/MH1(4,2),499
      INITIAL  MH1(26,1),100/MH1(26,2),499
      INITIAL  MH1(27,1),100/MH1(27,2),499
      INITIAL  MH1(28,1),0/MH1(28,2),99
      INITIAL  MH1(29,1),100/MH1(29,2),199
      INITIAL  MH1(30,1),200/MH1(30,2),299
      INITIAL  MH1(31,1),300/MH1(31,2),399
      INITIAL  MH1(32,1),400/MH1(32,2),499
      INITIAL  MH1(53,1),0/MH1(53,2),499
      INITIAL  MH1(54,1),0/MH1(54,2),499
      INITIAL  MH1(55,1),500/MH1(55,2),599
      INITIAL  MH1(56,1),600/MH1(56,2),699
      INITIAL  MH1(57,1),700/MH1(57,2),799
      INITIAL  MH1(58,1),800/MH1(58,2),899
      INITIAL  MH1(80,1),500/MH1(80,2),899
      INITIAL  MH1(81,1),500/MH1(81,2),899
      INITIAL  MH1(82,1),500/MH1(82,2),599
      INITIAL  MH1(83,1),600/MH1(83,2),699
      INITIAL  MH1(84,1),700/MH1(84,2),799
      INITIAL  MH1(85,1),800/MH1(85,2),899
      INITIAL  MH1(86,1),900/MH1(86,2),999
      INITIAL  MH1(107,1),500/MH1(107,2),999
      INITIAL  MH1(108,1),500/MH1(108,2),999
      INITIAL  MH1(109,1),0/MH1(109,2),999
      INITIAL  MH1(110,1),0/MH1(110,2),999
      INITIAL  MH1(111,1),0/MH1(111,2),999
      INITIAL  MH1(112,1),0/MH1(112,2),999
      INITIAL  MH1(113,1),0/MH1(113,2),999
      INITIAL  MH1(114,1),0/MH1(114,2),999
```

```
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       INITIAL     MH1(116,1),0/MH1(116,2),999
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       INITIAL     MH1(2,3),100/MH1(2,4),199
       INITIAL     MH1(3,3),100/MH1(3,4),199
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       INITIAL     MH1(26,3),100/MH1(26,4),199
       INITIAL     MH1(27,3),100/MH1(27,4),199
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       INITIAL     MH1(29,3),0/MH1(29,4),99
       INITIAL     MH1(30,3),0/MH1(30,4),99
       INITIAL     MH1(31,3),0/MH1(31,4),99
       INITIAL     MH1(32,3),0/MH1(32,4),99
       INITIAL     MH1(53,3),0/MH1(53,4),99
       INITIAL     MH1(54,3),0/MH1(54,4),99
       INITIAL     MH1(55,3),100/MH1(55,4),199
       INITIAL     MH1(56,3),100/MH1(56,4),199
       INITIAL     MH1(57,3),100/MH1(57.4),199
       INITIAL     MH1(58,3),100/MH1(58,4),199
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       INITIAL     MH1(110,3),0/MH1(110,4),199
       INITIAL     MH1(111,3),0/MH1(111,4),199
       INITIAL     MH1(112,3),0/MH1(112,4),199
       INITIAL     MH1(113,3),0/MH1(113,4),199
       INITIAL     MH1(114,3),0/MH1(114,4),199
       INITIAL     MH1(115,3),0/MH1(115,4),199
       INITIAL     MH1(116,3),0/MH1(116,4),199
       INITIAL     LS1-LS4/LS26-LS32/LS53-LS58/LS80-LS86/LS107-LS116
       INITIAL     MH1(87,1),900/MH1(87,2),999
       INITIAL     MH1(87,3),0/MH1(87,4),99
       INITIAL     LS87
       INITIAL     MH1(88,1),900/MH1(88,2),999
       INITIAL     MH1(88,3),0/MH1(88,4),99
       INITIAL     LS88
       INITIAL     MH1(59,1),800/MH1(59,2),899
       INITIAL     MH1(59,3),100/MH1(59,4),199
       INITIAL     LS59
 1     FVARIABLE   MH1(*1,1)+((1+MH1(*1,2)-MH1(*1,1))*RN7/1000)
 2     FVARIABLE   MH1(*1,3)+((1+MH1(*1,4)-MH1(*1.3))*RN7/1000)
 3     VARIABLE    MH1(*1,5)-P8
 4     VARIABLE    MH1(*1,6)-P9
 5     VARIABLE    (1-2)*XH100
 6     VARIABLE    (1-2)*XH101
 7     FVARIABLE   P5/K1780*K528*K5
 8     FVARIABLE   ((70-500)+(860/1000*RN6))/100*P15
 9     VARIABLE    C1-X1
*******************************************************************
*      PARAMETER UTILIZATION FOR MODEL TRANSACTIONS
```

```
*              P1 - CALL DISTRICT ( ZONE NUMBER)
**             P2 - RADIO OPERATOR QUEUE AND FACILITY
*              P3 - FIELD UNIT NUMBER ASSIGNED TO INCIDENT
**             P4 - NOT USED
**             P5 - UNIT TRAVEL DISTANCE
**             P6 - UNIT INVESTIGATION TIME
**             P7 - PREEMPT FACILITY
**             P8 - INCIDENT X-COORDINATE
**             P9 - INCIDENT Y-COORDINATE

****************************************************************************
*     FUNCTION TO DESCRIBE 1ST SHIFT (2300-0700) CALL INTERARRIVAL TIMES
 SHFT1 FUNCTION    RN2,C17
0.0   0.0   .11   50.   .22   100.  .33   150.  .41   200.  .47   250.
.51   300.  .60   350.  .65   400.  .71   450.  .78   500.  .86   550.
.89   600.  .91   650.  .94   700.  .99   750.  1.0   1600.

*      FUNCTION TO PROVIDE RANDOM VARIABILITY IN ACTION TIMES
 EXPON FUNCTION    RN3,C24
0     0     .1    .104  .2    .222  .3    .355  .4    .509  .5    .69
.6    .915  .7    1.2   .75   1.38  .8    1.6   .84   1.83  .88   2.12
.9    2.3   .92   2.52  .94   2.81  .95   2.99  .96   3.2   .97   3.5
.98   3.9   .99   4.6   .995  5.3   .998  6.2   .999  7.0   .9997 8.0



*      FUNCTION TO GIVE CALL GENERATION BY DISTRICT FREQUENCY
*      SOURCE... REPORTED 602-03'S FOR MAY,1971 TO MAY,1972
 DISTN FUNCTION    RN4,D18
.052  20.   .100  21.   .147  24.   .219  25.   .266  28.   .347  29.
.400  30.   .450  31.   .455  37.   .505  22.   .565  23.   .649  26.
.724  27.   .809  32.   .846  33.   .884  34.   .927  35.   1.000 36.



*      FOLLOWING FUNCTION ASSIGNS WEST DISTRICTS TO 1-9, EAST TO 10-18
 MAP   FUNCTION    P1,D18
20    1     21    2     22    10    23    11    24    3     25    4
26    12    27    13    28    5     29    6     30    7     31    8
32    14    33    15    34    16    35    17    36    18    37    9


 REMAP FUNCTION    P7,D18
1,1/2,2/3,3/4,4/5,28/6,29/7,30/8,31/9,32
10,55/11,56/12,57/13,58/14,82/15,83/16,84/17,85/18,86

*      MODULE TO SET VARIABLE PROCESSING TIME VALUES...
*      (TIMES IN 1/100 MINUTES)



*      FUNCTION TO DESCRIBE RADIO OPERATOR ACTION TIME
 TRAD  FUNCTION    RN1,C10
0.    1.    .13   15.   .43   30.   .61   45.   .73   60.   .79   75.
.84   90.   .87   106.  .90   121.  1.0   243.
```

```
*       FUNCTION TO DESCRIBE FIELD UNIT RESPONSE DELAY
 CALU  FUNCTION     RN1,C12
0.     5.     .04   7.     .11   13.    .25   20.    .49   27.    .68   33.
.60    40.    .88   46.    .93   53.    .97   60.    .99   66.    1.0   100.



 INV03 FUNCTION     RN5,C10
0      0      .04   100.   .20   500.   .36   1000.  .48   1500.  .58   2000.
.73    3000.  .84   4000.  .99   4800.  1.00  6100.



*       FUNCTION TO ALLOW INCREASED SERVICE DEMAND CONDITIONS
 GROW  FUNCTION     RN1,C2
0.0,0.5/1.0,0.5




*       GENERATE INCOMING CALLS
*       FOLLOWING CODE MODELS 602-09 REQUESTS FROM THE FIELD...
*       COMPLAINT DESK CLERKS ARE BYPASSED





*********************************************************************************
1         CALLS GENERATE   FN$SHFT1,FN$GROW,,,,15,F
          *     FIELD A OF CALLS BLOCK REPRESENTS MEAN INTERARRIVAL TIME
2               ASSIGN     1,FN$DISTN        ASSIGN CALL DISTRICT
3               ASSIGN     7,FN$MAP            GET DIST# IN P7
4               ASSIGN     1,FN$REMAP          CHANGE DIST# TO MATRIX VALUE
5               ASSIGN     8,V1
6               ASSIGN     9,V2
7               ASSIGN     15,V9               P15 = INTERARRIVAL TIME
8               SAVEVALUE  1,C1                SAVE THE CLOCK
9               ASSIGN     14,K0               CLEAR EAST-WEST SWITCH INDICATOR
10              TEST G     P7,K9,WRADD         GO TO WRADD IF DIST# LE 9
11              TEST LE    P7,K13,WEST1        GO TO WEST1 IF DIST# GT 13
12              ASSIGN     10,CAR51             FIRST CAR FOR DIST #3 IS CAR 51
13              ASSIGN     11,CAR75            LAST CAR FOR DIST #3 IS CAR75
14              ASSIGN     12,CAR76            LOAD LIMITS FOR DIST #4
15              ASSIGN     13,CAR00            TO TRY IF DIST #3 IS BUSY
16              TRANSFER   ,WEST2

17        WEST1 ASSIGN     10,CAR76             FIRST CAR FOR DIST #4 IS CAR 76
18              ASSIGN     11,CAR00            LAST CAR FOR DIST #4 IS CAR00
19              ASSIGN     12,CAR51            LOAD LIMITS FOR DIST#3
20              ASSIGN     13,CAR75            TO TRY IF DIST #4 IS BUSY

21        WEST2 ASSIGN     2,EAST

          *     FOLLOWING SEGMENT MODELS RADIO OPERATORS
```

```
     *      NOTE...IN GENERAL, RADIO OPERATORS WILL NOT CALL A BUSY UNIT

22   RADIO QUEUE      *2
23         SEIZE      *2
24         DEPART     *2
25         ADVANCE    FN$CALU
26         ADVANCE    FN$TRAD          RADIO OPERATOR DELAY
27         TRANSFER   ,MVCR
28   MVRT  SELECT NU  3,P10,P11,,,ZNFLA SELECT A CAR IN PRIME DISTRICT
29   ZNFL1 RELEASE    *2
30         TRANSFER   ,FIELD
31   WRADO ASSIGN     2,WEST
32         TEST LE    P7,K4,EAST1      GO TO EAST1 IF DIST# GT 4
33         ASSIGN     10,CAR01          FIRST CAR FOR DIST #1 IS 1
34         ASSIGN     11,CAR25         LAST CAR FOR DIST #1 IS CAR25
35         ASSIGN     12,CAR26         LOAD LIMITS FOR DIST#2
36         ASSIGN     13,CAR50         TO TRY IF DIST #1 IS BUSY
37         TRANSFER   ,EAST2

38   EAST1 ASSIGN     10,CAR26          FIRST CAR FOR DIST #2 IS CAR 26
39         ASSIGN     11,CAR50         LAST CAR FOR DIST #2 IS CAR50
40         ASSIGN     12,CAR01         LOAD LIMITS FOR DIST #1
41         ASSIGN     13,CAR25         TO TRY IF DIST #2 IS BUSY

42   EAST2 TRANSFER   ,RADIO

43   ZNFL  TEST NE    P14,K1,ZNFL2     GO LOOK FOR ASLESARG IF NO MATCH
44         SELECT NU  3,LIEU,MCYC7,,,OLOAD TRY LIEU & MCYC IF NO OTHER
45         TRANSFER   ,ZNFL1
46   ZNFLA SELECT NU  3,P12,P13,,,ZNFLB TRY NORTH (SOUTH) DISTRICT
47         TRANSFER   ,ZNFL1

48   ZNFLB TEST E     P14,K0,ZNFL      GO TRY LIEU-MCYC7 IF TRIED BEFORE
49         ASSIGN     14,K1            SET 'TRIED BEFORE' SWITCH
50         TEST E     P10,CAR01,ZNFLC  CHECK WHETHER EAST OR WEST
51         ASSIGN     10,CAR76         ASSIGN EAST DISTRICTS
52         ASSIGN     11,CAR00
53         ASSIGN     12,CAR51
54         ASSIGN     13,CAR75
55         TRANSFER   ,MVRT

56   ZNFLC ASSIGN     10,CAR01         ASSIGN WEST DISTRICTS
57         ASSIGN     11,CAR25
58         ASSIGN     12,CAR26
59         ASSIGN     13,CAR50
60         TRANSFER   ,MVRT

61   ZNFL2 ASSIGN     10,ASL1          LOAD LIMITS FOR ASL-SARG SEARCH
62         ASSIGN     11,SARG4
63         ASSIGN     12,P10
64         ASSIGN     13,P11
65         ASSIGN     14,K2
66         TRANSFER   ,MVRT

     *      FIELD UNIT OPERATIONS...
     *      FIELD UNITS...
     *        18 PATROL CARS
```

```
*           4 SERGEANTS
*           7 MOTORCYCLES
*           4 ASSISTANT SQUAD LEADERS
*           1 LIEUTENANT
*        NOTE... CURRENT PRACTICE IS 1 MAN IN EAST SIDE CARS,
*                2 MEN IN WEST SIDE CARS
*          ASSUME UNITS MOVE AT 20 MPH AVERAGE
*          OR 1760 FEET/MIN

67        FIELD ENTER       UNITS
68              SAVEVALUE   100,V3,H           COMPUTE X DISTANCE
69              TEST L      XH100,K0,XPOS1     TEST IF DISTANCE IS NEGATIVE
70              SAVEVALUE   100,V5,H           MULTIPLY BY -1 IF NEGATIVE
71        XPOS1 SAVEVALUE   101,V4,H           COMPUTE Y DISTANCE
72              TEST L      XH101,K0,YPOS1     TEST IF DISTANCE IS NEGATIVE
73              SAVEVALUE   101,V6,H           MULTIPLY BY -1 IF NEGATIVE
74        YPOS1 ASSIGN      5,XH100            ACCUMULATE TOTAL
75              ASSIGN      5+,XH101           OF X AND Y DISTANCES
76              TEST LE     P3,SARG2,SCN3
77              TEST G      P1,SARG2,SCN8
78        SCN4  ASSIGN      5+,K10             ADD PENALTY FOR EAST-WEST SWITCH
79              TRANSFER    ,SCN8
80        SCN3  TEST G      P1,SARG2,SCN4
81        SCN8  ASSIGN      13,P5              SAVE DISTANCE IN P13
82              ASSIGN      5,V7              CONVERT DISTANCE TO TIME
83              MSAVEVALUE  1,*3,5,P8,H
84              MSAVEVALUE  1,*3,6,P9,H
85        TYM03 ASSIGN      6,FN$INV03
86        TKOFF SEIZE       *3
87              ADVANCE     *5
88              ASSIGN      15,M1              SAVE TRANSIT TIME UNTIL TERMINATION
89              ADVANCE     *6
90        OUT01 RELEASE     *3
91              TRANSFER    ,FINSH
*********************************************************************
*        NOTE... BRANCH LOGIC FOR DISTRICT CAR BUSY CONDITION
*        BASIC ASSUMPTION WILL BE TO NOT QUEUE CALLS WHEN AN ADJACENT UNIT
*        IS FREE... ASL'S, SERGEANTS, OR MOTORS CAN HANDLE SOME CASES
*          CALL GOES TO...
*            NW DISTRICT ... CARS 1,2,3,4         , ASL1,SARG1,LIEUT,MOTORS
*            SW DISTRICT ... CARS 5,6,7,8,9       , ASL2,SARG2,LIEUT,MOTORS
*            NE DISTRICT ... CARS 10,11,12,13     , ASL3,SARG3,LIEUT,MOTORS
*            SE DISTRICT ... CARS 14,15,16,17,18, ASL4,SARG4,LIEUT,MOTORS
*********************************************************************


*********************************************************************

92        OLOAD RELEASE     *2                 RELEASE THE OPERATOR
93              TABULATE    XCESS             RECORD NON-ASSIGNABLE CALLS
94              TERMINATE                      REMOVE NON-ASSIGNABLE CALLS


95        FINSH LEAVE       UNITS             REMOVE SERVICE CALLS FROM FIELD
96              SAVEVALUE   *3+,P13,H          TALLY TRAVEL DISTANCE DOR THIS CAR
97              SAVEVALUE   105+,P13           TALLY TOTAL TRAVEL DISTANCE
98              TABULATE    TEN6
```

```
99          HELP        PRTAB,K2              PUNCH OUT TEN6 TABLE
100         TERMINATE   1                    REMOVE CALL FROM SYSTEM




     UNITS STORAGE     116

     FTIME TABLE      M1,0,100,180

     NOSVC TABLE      M1,0,100,180     TIME DELAY FOR NO ACTION CALLS

     *          TEN4 TABLE - TIME FROM CALL INITIATION UNTIL UNIT IS
     *          ON THE WAY TO THE SCENE.

     TEN4  TABLE      M1,0,100,180     TIME TO RECEIVE 'UNIT ON THE WAY'

     *          TEN6 TABLE - TIME FROM CALL INITIATION UNTIL UNIT
     *          IS AT THE SCENE

     TEN6  TABLE      P15,0,100,133     TIME UNTIL 'UNIT AT SCENE'

     *          TEN8 TABLE - TIME FROM CALL INITIATION UNTIL
     *          INCIDENT INVESTIGATION IS OVER.
     TEN8  TABLE      M1,0,500,180     TOTAL TIME FOR SERVICE OF FIELD CALLS

     XCESS TABLE      M1,0,100,180



     ************************************************************************


101       MVCR  ASSIGN      3,P13               SAVE P13 IN P3
102             ASSIGN      13,K1               INITIAL FACILITY NUMBER IS 1
103             ASSIGN      7,P15
104       MVCR1 GATE LS     *13,MOVEY           IGNORE NON-EXISTANT CARS
105             GATE NU     *13,MOVEY           IGNORE BUSY CARS
106             ASSIGN      4,P7                GET INTERRARRIVAL TIME IN P4
107       MVCR2 TEST G      P4,K100,MVCR5         IS TIME > 100 ?
108             ASSIGN      15,K100             YES,  MAKE A UNIT MOVE
109             ASSIGN      4-,K100             SUBTRACT 100 FROM TIME
110             TRANSFER    ,MVCR6              GO MAKE INCREMENTAL MOVE
111       MVCR5 ASSIGN      15,P4               MAKE MOVE TIME THE RESIDUE
112       MVCR6 MSAVEVALUE  1+,*13,5,V8,H       MAKE AN X-MOVE
113             TEST GE     MH1(*13,1),MH1(*13,5),MOVET  TEST FOR <XMIN
114             MSAVEVALUE  1,*13,5,MH1(*13,1),H         MAKE POSITION = XMIN
115             TRANSFER    ,MOVEV                       GO GENERATE Y-MOVE
116       MOVET TEST LE     MH1(*13,2),MH1(*13,5),MOVEV  TEST FOR > XMAX
117             MSAVEVALUE  1,*13,5,MH1(*13,2),H    MAKE POSITION = XMAX
118       MOVEV MSAVEVALUE  1+,*13,6,V8,H       MAKE A Y-MOVE
119             TEST GE     MH1(*13,3),MH1(*13,6),MOVEW  TEST FOR < YMIN
120             MSAVEVALUE  1,*13,6,MH1(*13,3),H         MAKE POSITION = YMIN
121             TRANSFER    ,MVCRN
122       MOVEW TEST LE     MH1(*13,4),MH1(*13,6),MVCRN   TEST FOR > YMAX
123             MSAVEVALUE  1,*13,6,MH1(*13,4),H         MAKE POSITION = YMAX
124       MVCRN TEST LE     P4,K100,MVCR2       GO MOVE AGAIN IF TIME > 100
```

```
125   MOVEY ASSIGN     13+,K1                    INCREMENT CAR NUMBER
126         TEST G     P13,K116,MVCR1     MOVE ANOTHER CAR IF NOT FINISHED
127         ASSIGN     13,P3              RESTORE P13 TO ORIGINAL VALUE
128         TRANSFER   ,MVRT                     RETURN TO DISPATCH

129         GENERATE   1,0,0,1            GENERATE 1 TRANSACTION AT T=0 & STOP
130         ASSIGN     1,K1               START WITH CAR #1
131   XXX1  GATE LR    *1,XXX2            IF CAR EXISTS, GO TO NEXT ONE
132         SEIZE      *1                 MAKE NON-EXISTANT CAR IN USE
133   XXX2  INDEX      1,1                INDEX TO NEXT CAR
134         TEST G     P1,K116,XXX1       TEST FOR LAST CAR PROCESSED
135         TERMINATE


*******FIRST SHIFT SIMULATION**********************************************
*         TIME REFERENCE = 1971



            START      1000,NP
            RESET
            INITIAL    XH1-XH34,0/X105,0/XH102,0
            INITIAL    X1,0
            START      500
            RESET
            INITIAL    XH1-XH34,0/X105,0/XH102,0
            INITIAL    X1,0
            START      500
            RESET
            INITIAL    XH1-XH34.0/X105,0/XH102,0
            INITIAL    X1,0
            START      500
            RESET
            INITIAL    XH1-XH34,0/X105,0/XH102,0
            INITIAL    X1.0
            START      500
            RESET
            INITIAL    XH1-XH34,0/X105,0/XH102,0
            INITIAL    X1,0
            START      500
            REPORT
            OUTPUT
            EJECT
            GRAPH      TF,TEN6
            ORIGIN     55,10
            X          ,1,3,0,1,30
            Y          0,4,25,2
      54    STATEMENT  58,24,PLOT OF TEN6 FREQUENCIES
            ENDGRAPH
            EJECT
            END
```

BLOCK NUMBER	SYMBOL	REFERENCES BY CARD NUMBER			
1	CALLS				
38	EAST1	353			
42	EAST2	358			
67	FIELD	351			
95	FINSH	431			
116	MOVET	500			
118	MOVEV	502	503		
122	MOVEW	506			
125	MOVEY	491	492		
101	MVCR	348			
124	MVCRN	508	509		
104	MVCR1	513			
107	MVCR2	511			
111	MVCR5	494			
112	MVCR6	497			
28	MVRT	380	386	393	515
92	OLOAD	368			
90	OUT01				
22	RADIO	365			
80	SCN3	416			
78	SCN4	420			
81	SCN8	417	419		
86	TKOFF				
85	TYMO3				
17	WEST1	326			
21	WEST2	331			
31	WRADO	325			
71	XPOS1	409			
131	XXX1	522			
133	XXX2	519			
74	YPOS1	412			
43	ZNFL	373			
46	ZNFLA	349			
48	ZNFLB	370			
56	ZNFLC	375			
29	ZNFL1	369	371		
61	ZNFL2	367			

FACILITY SYMBOLS AND CORRESPONDING NUMBERS

26	ASL1
53	ASL2
80	ASL3
107	ASL4
106	CAR00
1	CAR01
2	CAR02
3	CAR03
4	CAR04
5	CAR05
6	CAR06
7	CAR07
8	CAR08
9	CAR09
10	CAR10
11	CAR11
12	CAR12
13	CAR13
14	CAR14
15	CAR15
16	CAR16
17	CAR17
18	CAR18
19	CAR19
20	CAR20
21	CAR21
22	CAR22
23	CAR23
24	CAR24
25	CAR25
28	CAR26
29	CAR27
30	CAR28
31	CAR29
32	CAR30
33	CAR31
34	CAR32
35	CAR33
36	CAR34
37	CAR35
38	CAR36
39	CAR37
40	CAR38
41	CAR39
42	CAR40
43	CAR41
44	CAR42
45	CAR43
46	CAR44
47	CAR45
48	CAR46
49	CAR47
50	CAR48

51	CAR49
52	CAR50
55	CAR51
56	CAR52
57	CAR53
58	CAR54
59	CAR55
60	CAR56
61	CAR57
62	CAR58
63	CAR59
64	CAR60
65	CAR61
66	CAR62
67	CAR63
68	CAR64
69	CAR65
70	CAR66
71	CAR67
72	CAR68
73	CAR69
74	CAR70
75	CAR71
76	CAR72
77	CAR73
78	CAR74
79	CAR75
82	CAR76
83	CAR77
84	CAR78
85	CAR79
86	CAR80
87	CAR81
88	CAR82
89	CAR83
90	CAR84
91	CAR85
92	CAR86
93	CAR87
94	CAR88
95	CAR89
96	CAR90
97	CAR91
98	CAR92
99	CAR93
100	CAR94
101	CAR95
102	CAR96
103	CAR97
104	CAR98
105	CAR99
150	EAST
109	LIEU
110	MCYC1
111	MCYC2
112	MCYC3
113	MCYC4

114	MCYC5
115	MCYC6
116	MCYC7
27	SARG1
54	SARG2
81	SARG3
108	SARG4
149	WEST

STORAGE SYMBOLS AND CORRESPONDING NUMBERS

1 UNITS

QUEUE SYMBOLS AND CORRESPONDING NUMBERS

150	EAST
149	WEST

TABLE SYMBOLS AND CORRESPONDING NUMBERS

3	FTIME
4	NUSVC
5	TEN4
2	TEN6
6	TEN8
1	XCESS

FUNCTION SYMBOLS AND CORRESPONDING NUMBERS

7	CALU
3	DISTN
2	EXPUN
9	GROW
8	INVU3
4	MAP
5	REMAP
1	SHFT1
6	TRAD

APPENDIX III

GPSS/360 LISTING OF AVL MODEL

*** G P S S / 3 6 0 / O S V E R S I O N 1 * * *
*** IBM PROGRAM NUMBER 360A-CS-17X (V1M4) ***

64

```
BLOCK
NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G          COMMENTS                             CARD
                                                                                      NUMBER
        *
        *       ORLANDO POLICE DEPARTMENT COMMAND/CONTROL CENTER SIMULATION
        *
        *       NOTE...DETECTIVE ACTIVITY, ACCIDENT INVESTIGATION, AND
        *       OTHER 'OVERHEAD' RADIO TRAFFIC NOT SIMULATED IN THIS VERSION
        *
        *
        *       CLOCK TIME IN 1/100 MINUTES
        *
        *
        *
        *

        *       ASSUME UNITS MOVE AT 20 MPH AVERAGE OR 1760 FEET/MIN
        *       EACH X-Y MOVEMENT IS 0-880 FEET WITH A UNIFORM DISTRIBUTION
        *       LOGIC SWITCHES 1-18 INDICATE WHETHER OR NOT A UNIT
        *       IS IN ITS ZONE.
        *
        *       LOGIC SWITCH SET - UNIT OUT OF ZONE
        *       LOGIC SWITCH RESET - UNIT IN ZONE
        *       EACH POSITION ON THE SACLE IS ASSUMED TO BE 0.01 MILE
        *       OR 528 FEET.
        *       CITY IS ASSUMED TO BE 10 MILES SQUARE.
         FIND1 STARTMACRO
               ASSIGN      1,#A                 LOAD FIRST FACILITY FOR SEARCH
               ASSIGN      7,#B                 LOAD LAST FACILITY FOR SEARCH
               TRANSFER    SBR,$CAN1,14
               ENDMACRO

         CAR01 EQU         1,F
         CAR02 EQU         2,F
         CAR03 EQU         3,F
         CAR04 EQU         4,F
         CAR05 EQU         5,F
         CAR06 EQU         6,F
         CAR07 EQU         7,F
         CAR08 EQU         8,F
         CAR09 EQU         9,F
         CAR10 EQU         10,F
         CAR11 EQU         11,F
         CAR12 EQU         12,F
         CAR13 EQU         13,F
         CAR14 EQU         14,F
         CAR15 EQU         15,F
         CAR16 EQU         16,F
         CAR17 EQU         17,F
         CAR18 EQU         18,F
         CAR19 EQU         19,F
         CAR20 EQU         20,F
         CAR21 EQU         21,F
         CAR22 EQU         22,F
         CAR23 EQU         23,F
         CAR24 EQU         24,F
         CAR25 EQU         25,F
         ASL1  EQU         26,F
```

```
SARG1 EQU      27,F
CAR26 EQU      28,F
CAR27 EQU      29,F
CAR28 EQU      30,F
CAR29 EQU      31,F
CAR30 EQU      32,F
CAR31 EQU      33,F
CAR32 EQU      34,F
CAR33 EQU      35,F
CAR34 EQU      36,F
CAR35 EQU      37,F
CAR36 EQU      38,F
CAR37 EQU      39,F
CAR38 EQU      40,F
CAR39 EQU      41,F
CAR40 EQU      42,F
CAR41 EQU      43,F
CAR42 EQU      44,F
CAR43 EQU      45,F
CAR44 EQU      46,F
CAR45 EQU      47,F
CAR46 EQU      48,F
CAR47 EQU      49,F
CAR48 EQU      50,F
CAR49 EQU      51,F
CAR50 EQU      52,F
ASL2  EQU      53,F
SARG2 EQU      54,F
CAR51 EQU      55,F
CAR52 EQU      56,F
CAR53 EQU      57,F
CAR54 EQU      58,F
CAR55 EQU      59,F
CAR56 EQU      60,F
CAR57 EQU      61,F
CAR58 EQU      62,F
CAR59 EQU      63,F
CAR60 EQU      64,F
CAR61 EQU      65,F
CAR62 EQU      66,F
CAR63 EQU      67,F
CAR64 EQU      68,F
CAR65 EQU      69,F
CAR66 EQU      70,F
CAR67 EQU      71,F
CAR68 EQU      72,F
CAR69 EQU      73,F
CAR70 EQU      74,F
CAR71 EQU      75,F
CAR72 EQU      76,F
CAR73 EQU      77,F
CAR74 EQU      78,F
CAR75 EQU      79,F
ASL3  EQU      80,F
SARG3 EQU      81,F
CAR76 EQU      82,F
CAR77 EQU      83,F
```

```
CAR78 EQU      84,F
CAR79 EQU      85,F
CAR80 EQU      86,F
CAR81 EQU      87,F
CAR82 EQU      88,F
CAR83 EQU      89,F
CAR84 EQU      90,F
CAR85 EQU      91,F
CAR86 EQU      92,F
CAR87 EQU      93,F
CAR88 EQU      94,F
CAR89 EQU      95,F
CAR90 EQU      96,F
CAR91 EQU      97,F
CAR92 EQU      98,F
CAR93 EQU      99,F
CAR94 EQU      100,F
CAR95 EQU      101,F
CAR96 EQU      102,F
CAR97 EQU      103,F
CAR98 EQU      104,F
CAR99 EQU      105,F
CAR00 EQU      106,F
ASL4  EQU      107,F
SARG4 EQU      108,F
LIEU  EQU      109,F
MCYC1 EQU      110,F
MCYC2 EQU      111,F
MCYC3 EQU      112,F
MCYC4 EQU      113,F
MCYC5 EQU      114,F
MCYC6 EQU      115,F
MCYC7 EQU      116,F
WEST  EQU      149,F,Q
EAST  EQU      150,F,Q
1     MATRIX   H,120,8
      INITIAL  MH1(1,1),100/MH1(1,2),199
      INITIAL  MH1(2,1),200/MH1(2,2),299
      INITIAL  MH1(3,1),300/MH1(3,2),399
      INITIAL  MH1(4,1),400/MH1(4,2),499
      INITIAL  MH1(26,1),100/MH1(26,2),499
      INITIAL  MH1(27,1),100/MH1(27,2),499
      INITIAL  MH1(28,1),0/MH1(28,2),99
      INITIAL  MH1(29,1),100/MH1(29,2),199
      INITIAL  MH1(30,1),200/MH1(30,2),299
      INITIAL  MH1(31,1),300/MH1(31,2),399
      INITIAL  MH1(32,1),400/MH1(32,2),499
      INITIAL  MH1(53,1),0/MH1(53,2),499
      INITIAL  MH1(54,1),0/MH1(54,2),499
      INITIAL  MH1(55,1),500/MH1(55,2),599
      INITIAL  MH1(56,1),600/MH1(56,2),699
      INITIAL  MH1(57,1),700/MH1(57,2),799
      INITIAL  MH1(58,1),800/MH1(58,2),899
      INITIAL  MH1(80,1),500/MH1(80,2),899
      INITIAL  MH1(81,1),500/MH1(81,2),899
      INITIAL  MH1(82,1),500/MH1(82,2),599
      INITIAL  MH1(83,1),600/MH1(83,2),699
```

```
      INITIAL     MH1(84,1),700/MH1(84,2),799
      INITIAL     MH1(85,1),800/MH1(85,2),899
      INITIAL     MH1(86,1),900/MH1(86,2),999
      INITIAL     MH1(107,1),500/MH1(107,2),999
      INITIAL     MH1(108,1),500/MH1(108,2),999
      INITIAL     MH1(109,1),0/MH1(109,2),999
      INITIAL     MH1(110,1),0/MH1(110,2),999
      INITIAL     MH1(111,1),0/MH1(111,2),999
      INITIAL     MH1(112,1),0/MH1(112,2),999
      INITIAL     MH1(113,1),0/MH1(113,2),999
      INITIAL     MH1(114,1),0/MH1(114,2),999
      INITIAL     MH1(115,1),0/MH1(115,2),999
      INITIAL     MH1(116,1),0/MH1(116,2),999
      INITIAL     MH1(1,3),100/MH1(1,4),199
      INITIAL     MH1(2,3),100/MH1(2,4),199
      INITIAL     MH1(3,3),100/MH1(3,4),199
      INITIAL     MH1(4,3),100/MH1(4,4),199
      INITIAL     MH1(26,3),100/MH1(26,4),199
      INITIAL     MH1(27,3),100/MH1(27,4),199
      INITIAL     MH1(28,3),0/MH1(28,4),99
      INITIAL     MH1(29,3),0/MH1(29,4),99
      INITIAL     MH1(30,3),0/MH1(30,4),99
      INITIAL     MH1(31,3),0/MH1(31,4),99
      INITIAL     MH1(32,3),0/MH1(32,4),99
      INITIAL     MH1(53,3),0/MH1(53,4),99
      INITIAL     MH1(54,3),0/MH1(54,4),99
      INITIAL     MH1(55,3),100/MH1(55,4),199
      INITIAL     MH1(56,3),100/MH1(56,4),199
      INITIAL     MH1(57,3),100/MH1(57,4),199
      INITIAL     MH1(58,3),100/MH1(58,4),199
      INITIAL     MH1(80,3),100/MH1(80,4),199
      INITIAL     MH1(81,3),100/MH1(81,4),199
      INITIAL     MH1(82,3),0/MH1(82,4),99
      INITIAL     MH1(83,3),0/MH1(83,4),99
      INITIAL     MH1(84,3),0/MH1(84,4),99
      INITIAL     MH1(85,3),0/MH1(85,4),99
      INITIAL     MH1(86,3),0/MH1(86,4),99
      INITIAL     MH1(107,3),0/MH1(107,4),99
      INITIAL     MH1(108,3),0/MH1(108,4),99
      INITIAL     MH1(109,3),0/MH1(109,4),199
      INITIAL     MH1(110,3),0/MH1(110,4),199
      INITIAL     MH1(111,3),0/MH1(111,4),199
      INITIAL     MH1(112,3),0/MH1(112,4),199
      INITIAL     MH1(113,3),0/MH1(113,4),199
      INITIAL     MH1(114,3),0/MH1(114,4),199
      INITIAL     MH1(115,3),0/MH1(115,4),199
      INITIAL     MH1(116,3),0/MH1(116,4),199
      INITIAL     LS1-LS4/LS26-LS32/LS53-LS58/LS80-LS86/LS107-LS116
1     FVARIABLE   MH1(*1,1)+((1+MH1(*1,2)-MH1(*1,1))*RN7/1000)
2     FVARIABLE   MH1(*1,3)+((1+MH1(*1,4)-MH1(*1,3))*RN7/1000)
3     VARIABLE    MH1(*1,*11)-P8
4     VARIABLE    MH1(*1,*12)-P9
5     VARIABLE    (1-2)*XH100
6     VARIABLE    (1-2)*XH101
7     FVARIABLE   P5/K1780*K528*K5
8     FVARIABLE   ((70-500)+(860/1000*RN6))/100*P15
9     VARIABLE    C1-X1
```

```
10      FVARIABLE  MH1(*13,5)-30+(60*RN8/1000) RESOLUTION = 1500 FT
11      FVARIABLE  MH1(*13,6)-30+(60*RN8/1000) RESULUTION = 1500 FT
12      VARIABLE   P15-P5
13      VARIABLE   (1-2)*P10
************************************************************************
*       PARAMETER UTILIZATION FOR MODEL TRANSACTIONS
*                  P1 - CALL DISTRICT ( ZONE NUMBER)
**                 P2 - RADIO OPERATOR QUEUE AND FACILITY
*                  P3 - FIELD UNIT NUMBER ASSIGNED TO INCIDENT
**                 P4 - NOT USED
**                 P5 - UNIT TRAVEL DISTANCE
**                 P6 - UNIT INVESTIGATION TIME
**                 P7 - PREEMPT FACILITY
**                 P8 - INCIDENT X-COORDINATE
**                 P9 - INCIDENT Y-COORDINATE

************************************************************************
*       FUNCTION TO DESCRIBE 1ST SHIFT (2300-0700) CALL INTERARRIVAL TIMES
 SHFT1 FUNCTION    RN2,C17
0.0   0.0   .11   50.   .22   100.  .33   150.  .41   200.  .47   250.
.51   300.  .60   350.  .65   400.  .71   450.  .78   500.  .86   550.
.89   600.  .91   650.  .94   700.  .99   750.  1.0   1600.

*       FUNCTION TO PROVIDE RANDOM VARIABILITY IN ACTION TIMES
 EXPON FUNCTION    RN3,C24
0     0     .1    .104  .2    .222  .3    .355  .4    .509  .5    .69
.6    .915  .7    1.2   .75   1.38  .8    1.6   .84   1.83  .88   2.12
.9    2.3   .92   2.52  .94   2.81  .95   2.99  .96   3.2   .97   3.5
.98   3.9   .99   4.6   .995  5.3   .998  6.2   .999  7.0   .9997 8.0



*       FUNCTION TO GIVE CALL GENERATION BY DISTRICT FREQUENCY
*       SOURCE... REPORTED 602-03'S FOR MAY,1971 TO MAY,1972
 DISTN FUNCTION    RN4,D18
.052  20.   .100  21.   .147  24.   .219  25.   .266  28.   .347  29.
.400  30.   .450  31.   .455  37.   .505  22.   .565  23.   .649  26.
.724  27.   .809  32.   .846  33.   .884  34.   .927  35.   1.000 36.



*       FOLLOWING FUNCTION ASSIGNS WEST DISTRICTS TO 1-9, EAST TO 10-18
 MAP    FUNCTION   P1,D18
20    1     21    2     22    10    23    11    24    3     25    4
26    12    27    13    28    5     29    6     30    7     31    8
32    14    33    15    34    16    35    17    36    18    37    9

 REMAP FUNCTION    P7,D18
1,1/2,2/3,3/4,4/5,28/6,29/7,30/8,31/9,32
10,55/11,56/12,57/13,58/14,82/15,83/16,84/17,85/18,86


*       MODULE TO SET VARIABLE PROCESSING TIME VALUES...
*       (TIMES IN 1/100 MINUTES)
```

```
*       FUNCTION TO DESCRIBE RADIO OPERATOR ACTION TIME
 TRAD  FUNCTION    RN1,C10
0.     1.    .13    15.   .43    30.   .61    45.   .73    60.   .79    75.
.84    90.   .87    106.  .90    121.  1.0    243.



*       FUNCTION TO DESCRIBE FIELD UNIT RESPONSE DELAY
 CALU  FUNCTION    RN1,C12
0.     5.    .04    7.    .11    13.   .25    20.   .49    27.   .68    33.
.60    40.   .88    46.   .93    53.   .97    60.   .99    66.   1.0    100.

 INV03 FUNCTION    RN5,C10
0      0     .04    100.  .20    500.  .36    1000. .48    1500. .58    2000.
.73    3000. .84    4000. .99    4800. 1.00   6100.



*       FUNCTION TO ALLOW INCREASED SERVICE DEMAND CONDITIONS
 GROW  FUNCTION    RN1,C2
0.0,0.5/1.0,0.5




*       GENERATE INCOMING CALLS
*       FOLLOWING CODE MODELS 602-09 REQUESTS FROM THE FIELD...
*       COMPLAINT DESK CLERKS ARE BYPASSED






**********************************************************************
1         CALLS GENERATE   FN$SHFT1,FN$GROW,,,,15,F
          *     FIELD A OF CALLS BLOCK REPRESENTS MEAN INTERARRIVAL TIME
2               ASSIGN     1,FN$DISTN          ASSIGN CALL DISTRICT
3               ASSIGN     7,FN$MAP            GET DIST# IN P7
4               ASSIGN     1,FN$REMAP          CHANGE DIST# TO MATRIX VALUE
5               ASSIGN     8,V1
6               ASSIGN     9,V2
7               ASSIGN     15,V9               P15 = INTERARRIVAL TIME
8               SAVEVALUE  1,C1                SAVE THE CLOCK
9               TEST G     P7,K9,WRADO

10        WEST2 ASSIGN     2,EAST

          *     FOLLOWING SEGMENT MODELS RADIO OPERATORS
          *     NOTE...IN GENERAL, RADIO OPERATORS WILL NOT CALL A BUSY UNIT

11        RADIO QUEUE      *2
12              SEIZE      *2
13              DEPART     *2
14              ADVANCE    FN$CALU
15              ADVANCE    FN$TRAD           RADIO OPERATOR DELAY
16              TRANSFER   ,MVCR              GO MOVE THE CARS
```

```
17      MVRT  ASSIGN     4,P1                 SAVE MATRIX DIST# IN P4                 341
18            ASSIGN     11,K7                USE AVL COORDINATES TO MAKE             342
19            ASSIGN     12,K8                A DISPATCH DECISION                     343
20            ASSIGN     5,K32767             SET MAX ØISTANCE IN P5                  344
        FIND1 MACRO      CAR01,CAR25                                                  345
21            ASSIGN     1,CAR01                                                      345
22            ASSIGN     7,CAR25                                                      345
23            TRANSFER   SBR,SCAN1,14                                                 345
        FIND1 MACRO      CAR26,CAR50                                                  346
24            ASSIGN     1,CAR26                                                      346
25            ASSIGN     7,CAR50                                                      346
26            TRANSFER   SBR,SCAN1,14                                                 346
        FIND1 MACRO      CAR51,CAR75                                                  347
27            ASSIGN     1,CAR51                                                      347
28            ASSIGN     7,CAR75                                                      347
29            TRANSFER   SBR,SCAN1,14                                                 347
        FIND1 MACRO      CAR76,CAR00                                                  348
30            ASSIGN     1.CAR76                                                      348
31            ASSIGN     7,CAR00                                                      348
32            TRANSFER   SBR,SCAN1,14                                                 348
33            TEST E     P5,K32767,SCGD1      BRANCH ON CAR FOUND                     349
        FIND1 MACRO      ASL1,SARG1                                                   350
34            ASSIGN     1,ASL1                                                       350
35            ASSIGN     7,SARG1                                                      350
36            TRANSFER   SBR,SCAN1,14                                                 350
        FIND1 MACRO      ASL2,SARG2                                                   351
37            ASSIGN     1,ASL2                                                       351
38            ASSIGN     7,SARG2                                                      351
39            TRANSFER   SBR,SCAN1,14                                                 351
        FIND1 MACRO      ASL3,SARG3                                                   352
40            ASSIGN     1,ASL3                                                       352
41            ASSIGN     7,SARG3                                                      352
42            TRANSFER   SBR,SCAN1,14                                                 352
        FIND1 MACRO      ASL4,SARG4                                                   353
43            ASSIGN     1,ASL4                                                       353
44            ASSIGN     7,SARG4                                                      353
45            TRANSFER   SBR,SCAN1,14                                                 353
46            TEST E     P5,K32767,SCGD1      BRANCH ON CAR FOUND                     354
        FIND1 MACRO      LIEU,MCYC7                                                   355
47            ASSIGN     1,LIEU                                                       355
48            ASSIGN     7,MCYC7                                                      355
49            TRANSFER   SBR,SCAN1,14                                                 355
50            TEST NE    P5,K32767,OLOAD      GIVE UP IF NO CAR AVAILABLE             356
51      SCGD1 ASSIGN     13,P3                SAVE CAR# IN P13                        357
52            ASSIGN     5,K32767             SET MAX DISTANCE IN P5                  358
53            ASSIGN     11,K5                USE ACTUAL CAR LOCATION TO              359
54            ASSIGN     12,K6                CHOOSE PRECISE DISTANCE                 360
        FIND1 MACRO      CAR01,CAR25                                                  361
55            ASSIGN     1,CAR01                                                      361
56            ASSIGN     7,CAR25                                                      361
57            TRANSFER   SBR,SCAN1,14                                                 361
        FIND1 MACRO      CAR26,CAR50                                                  362
58            ASSIGN     1,CAR26                                                      362
59            ASSIGN     7,CAR50                                                      362
60            TRANSFER   SBR,SCAN1,14                                                 362
        FIND1 MACRO      CAR51,CAR75                                                  363
61            ASSIGN     1,CAR51                                                      363
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62              ASSIGN     7,CAR75                                                       363
63              TRANSFER   SBR,SCAN1,14                                                  363
         FIND1  MACRO      CAR76,CARUO                                                   364
64              ASSIGN     1,CAR76                                                       364
65              ASSIGN     7,CARUO                                                       364
66              TRANSFER   SBR,SCAN1,14                                                  364
67              TEST E     P5,K32767,SCGD2    BRANCH ON CAR FOUND                        365
         FIND1  MACRO      ASL1,SARG1                                                    366
68              ASSIGN     1,ASL1                                                        366
69              ASSIGN     7,SARG1                                                       366
70              TRANSFER   SBR,SCAN1,14                                                  366
         FIND1  MACRO      ASL2,SARG2                                                    367
71              ASSIGN     1,ASL2                                                        367
72              ASSIGN     7,SARG2                                                       367
73              TRANSFER   SBR,SCAN1,14                                                  367
         FIND1  MACRO      ASL3,SARG3                                                    368
74              ASSIGN     1,ASL3                                                        368
75              ASSIGN     7,SARG3                                                       368
76              TRANSFER   SBR,SCAN1,14                                                  368
         FIND1  MACRO      ASL4,SARG4                                                    369
77              ASSIGN     1,ASL4                                                        369
78              ASSIGN     7,SARG4                                                       369
79              TRANSFER   SBR,SCAN1,14                                                  369
80              TEST E     P5,K32767,SCGD2    BRANCH ON CAR FOUND                        370
         FIND1  MACRO      LIEU,MCYC7                                                    371
81              ASSIGN     1,LIEU                                                        371
82              ASSIGN     7,MCYC7                                                       371
83              TRANSFER   SBR,SCAN1,14                                                  371
84       SCGD2  ASSIGN     14,K0              CLEAR P14 TO ZERO                          372
85              ASSIGN     1,P13              PUT AVL CAR# IN P1                         373
86              SAVEVALUE  100,V3,H           COMPUTE X DISTANCE                         374
87              TEST L     XH100,K0,XPOS1     TEST IF DISTANCE IS NEGATIVE               375
88              SAVEVALUE  100,V5,H           MULTIPLY BY -1 IF NEGATIVE                 376
89       XPOS1  SAVEVALUE  101,V4,H           COMPUTE Y DISTANCE                         377
90              TEST L     XH101,K0,YPOS1     TEST IF DISTANCE IS NEGATIVE               378
91              SAVEVALUE  101,V6,H           MULTIPLY BY -1 IF NEGATIVE                 379
92       YPOS1  ASSIGN     15,XH100           ACCUMULATE TOTAL                           380
93              ASSIGN     15+,XH101          OF X AND Y DISTANCES                       381
94              TEST L     P5,P15,SCGD3       TEST FOR DISPATCH ERROR                    382
95              ASSIGN     14,V12             SAVE WRONG DISPATCH DISTANCE IN P14        383
96       SCGD3  ASSIGN     3,P13              PUT AVL-DISPATCHED CAR NUMBER IN P3        384
97              ASSIGN     5,P15              GET AVL REAL DISTANCE IN P5                385
98              ASSIGN     1,P4           GET INCIDENT MATRIX ADDR IN P1                 386
99       ZNFL1  RELEASE    *2                 RELEASE THE RADIO OPERATOR                 387
100             TRANSFER   ,FIELD                                                        388
101      WRADO  ASSIGN     2,WEST                                                        389
                                                                                         390
102      EAST2  TRANSFER   ,RADIO                                                        391
                                                                                         392
103      SCAN1  GATE NU    *1,SCAN4           DON'T LOOK IF CAR IS BUSY                  393
104             ASSIGN     10,V3              CALCULATE X-DISTANCE                       394
105             TEST L     P10,K0,SCAN2       TEST FOR COMPUTED DISTANCE LT ZERO         395
106             ASSIGN     10,V13             MAKE DISTANCE POSITIVE                     396
107      SCAN2  ASSIGN     6,P10              ACCUMULATE X-DISTANCE                      397
108             ASSIGN     10,V4              CALCULATE Y-DISTANCE                       398
109             TEST L     P10,K0,SCAN3       TEST FOR COMPUTED DISTANCE LT ZERO         399
110             ASSIGN     10,V13             MAKE DISTANCE POSITIVE                     400
```

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111      SCAN3 ASSIGN    6+,P10             DISTANCE
112            TEST LE   P1,SARG2,SCN3      DROP THRU IF CAR# IS IN EAST ZONE
113            TEST G    P4,SARG2,SCN8      DROP THRU IF CALL IS IN WEST ZONE
114      SCN4  ASSIGN    6+,K10             ADD PENALTY FOR EAST-WEST SWITCH
115            TRANSFER  ,SCN8
116      SCN3  TEST G    P4,SARG2,SCN4   ADD PENALTY IF CALL IS IN EAST ZONE
117      SCN8  TEST G    P5,P6,SCAN4    TEST IF DISTANCE BETTER THAN LAST
118            ASSIGN    5,P6               SAVE NEW VALUE AS BETTER THAN LAST
119            ASSIGN    3,P1               SAVE FACILITY NUMBER FOR BEST
120      SCAN4 TEST L    P1,P7,SCANO        EXIT IF ALL FACILITIES CHECKED
121            INDEX     1,1                INDEX TO NEXT FACILITY
122            TRANSFER  ,SCAN1             GO CHECK NEXT FACILITY
123      SCANO TRANSFER  P,14,1             RETURN TO MAIN PATH
         ****************************************************************
         *     FIELD UNIT OPERATIONS...
         *     FIELD UNITS...
         *       18 PATROL CARS
         *        4 SERGEANTS
         *        7 MOTORCYCLES
         *        4 ASSISTANT SQUAD LEADERS
         *        1 LIEUTENANT
         *     NOTE... CURRENT PRACTICE IS 1 MAN IN EAST SIDE CARS,
         *             2 MEN IN WEST SIDE CARS
         *       ASSUME UNITS MOVE AT 20 MPH AVERAGE
         *       OR 1760 FEET/MIN

124      FIELD ENTER       UNITS
125            ASSIGN    13,P5              SAVE DISPATCH DISTANCE IN P13
126            ASSIGN    5,V7            CONVERT DISTANCE TO TIME
127            MSAVEVALUE 1,*3,5,P8,H
128            MSAVEVALUE 1,*3,6,P9,H

         *     NOTE...TRAVEL AND INVESTIGATION TIMES ARE A FUNCTION OF THE TYPE
         *     OF SERVICE CALL CURRENTLY BEING PROCESSED

129      TYMO3 ASSIGN    6,FN$INVO3
130      TKOFF SEIZE     *3
131            ADVANCE   *5
132            ASSIGN    15,M1              SAVE TRANSIT TIME UNTIL TERMINATION
133            ADVANCE   *6
134      OUTO1 RELEASE   *3
135            TRANSFER  ,FINSH
         ****************************************************************
         *     NOTE... BRANCH LOGIC FOR DISTRICT CAR BUSY CONDITION
         *     BASIC ASSUMPTION WILL BE TO NOT QUEUE CALLS WHEN AN ADJACENT UNIT
         *     IS FREE... ASL'S, SERGEANTS, OR MOTORS CAN HANDLE SOME CASES
         *       CALL GOES TO...
         *         NW DISTRICT ... CARS 1,2,3,4         , ASL1,SARG1,LIEUT,MOTORS
         *         SW DISTRICT ... CARS 5,6,7,8,9       , ASL2,SARG2,LIEUT,MOTORS
         *         NE DISTRICT ... CARS 10,11,12,13     , ASL3,SARG3,LIEUT,MOTORS
         *         SE DISTRICT ... CARS 14,15,16,17,18, ASL4,SARG4,LIEUT,MOTORS
         ****************************************************************


         ****************************************************************

136      OLOAD RELEASE   *2                 RELEASE THE OPERATOR
```

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137          TABULATE    XCESS            RECORD NON-ASSIGNABLE CALLS
138          TERMINATE                      REMOVE NON-ASSIGNABLE CALLS


139    FINSH LEAVE       UNITS            REMOVE SERVICE CALLS FROM FIELD
140          SAVEVALUE   *3+,P13,H        TALLY THIS CAR'S TRAVEL DISTANCE
141          SAVEVALUE   105+,P13           TALLY TOTAL VEHICLE TRAVEL DISTANCE
142          TABULATE    TEN6
143          TEST NE     P14,K0,FIN01       DON'T TAB DISTANCE IF NO ERROR
144          TABULATE    WRONG TABULATE DISTANCE TRAVELED DUE TO DISPATCH ERROR
145    FIN01 TERMINATE   1                  REMOVE CALL FROM SYSTEM


       UNITS STORAGE     116

       FTIME TABLE      M1,0,100,180

       NOSVC TABLE      M1,0,100,180    TIME DELAY FOR NO ACTION CALLS

       *     TEN4 TABLE - TIME FROM CALL INITIATION UNTIL UNIT IS
       *     ON THE WAY TO THE SCENE.

       TEN4  TABLE      M1,0,100,180    TIME TO RECEIVE 'UNIT ON THE WAY'

       *     TEN6 TABLE - TIME FROM CALL INITIATION UNTIL UNIT
       *     IS AT THE SCENE

       TEN6  TABLE      P15,0,100,133     TIME UNTIL 'UNIT AT SCENE'

       *     TEN8 TABLE - TIME FROM CALL INITIATION UNTIL
       *     INCIDENT INVESTIGATION IS OVER.
       TEN8  TABLE      M1,0,500,180    TOTAL TIME FOR SERVICE OF FIELD CALLS

       XCESS TABLE      M1,0,100,180

       WRONG TABLE      P14,0,10,133    WRONG DISPATCH DISTANCE TABLE

146    MVCR  ASSIGN     3,P13               SAVE P13 IN P3
147          ASSIGN     13,K1               INITIAL FACILITY NUMBER IS 1
148          ASSIGN     7,P15
149    MVCR1 GATE LS    *13,MUVEY           IGNORE NON-EXISTANT CARS
150          GATE NU    *13,MUVEY           IGNORE BUSY CARS
151          ASSIGN     4,P7                GET INTERRARRIVAL TIME IN P4
152    MVCR2 TEST G     P4,K100,MVCR5         IS TIME > 100 ?
153          ASSIGN     15,K100             YES,  MAKE A UNIT MOVE
154          ASSIGN     4-,K100             SUBTRACT 100 FROM TIME
155          TRANSFER   ,MVCR6              GO MAKE INCREMENTAL MOVE
156    MVCR5 ASSIGN     15,P4               MAKE MOVE TIME THE RESIDUE
157    MVCR6 MSAVEVALUE 1+,*13,5,V8,H     MAKE AN X-MOVE
158          TEST GE    MH1(*13,1),MH1(*13,5),MUVET  TEST FOR <XMIN
159          MSAVEVALUE 1,*13,5,MH1(*13,1),H           MAKE POSITION = XMIN
160          TRANSFER   ,MOVEV                         GO GENERATE Y-MOVE
161    MOVET TEST LE    MH1(*13,2),MH1(*13,5),MOVEV  TEST FOR > XMAX
162          MSAVEVALUE 1,*13,5,MH1(*13,2),H    MAKE POSITION = XMAX
163    MOVEV MSAVEVALUE 1+,*13,6,V8,H     MAKE A Y-MOVE
164          TEST GE    MH1(*13,3),MH1(*13,6),MOVEW  TEST FOR < YMIN
165          MSAVEVALUE 1,*13,6,MH1(*13,3),H           MAKE POSITION = YMIN
```

```
166              TRANSFER    ,MVCRN
167       MOVEW  TEST LE     MH1(*13,4),MH1(*13,6),MVCRN    TEST FOR > YMAX
168              MSAVEVALUE  1,*13,6,MH1(*13,4),H            MAKE POSITION = YMAX
169       MVCRN  TEST LE     P4,K100,MVCR2       GO MOVE AGAIN IF TIME > 100
170              MSAVEVALUE  1,*13,7,V10,H       COMPUTE AVL COORDINATES
171              MSAVEVALUE  1,*13,8,V11,H
172       MOVEY  ASSIGN      13+,K1                          INCREMENT CAR NUMBER
173              TEST G      P13,K116,MVCR1      MOVE ANOTHER CAR IF NOT FINISHED
174              ASSIGN      13,P3               RESTORE P13 TO ORIGINAL VALUE
175              TRANSFER    ,MVRT                           RETURN TO DISPATCH

176              GENERATE    1,0,0,1             GENERATE 1 TRANSACTION AT T=0 & STOP
177              ASSIGN      1,K1                START WITH CAR #1
178       XXX1   GATE LR     *1,XXX2             IF CAR EXISTS, GO TO NEXT ONE
179              SEIZE       *1                  MAKE NON-EXISTANT CAR IN USE
180       XXX2   INDEX       1,1                 INDEX TO NEXT CAR
181              TEST G      P1,K116,XXX1        TEST FOR LAST CAR PROCESSED
182              TERMINATE

          *      NOTE... RESET CARD WIPES OUT ACCUMULATED STATISTICS



          *******FIRST SHIFT SIMULATION*****************************************
          *          TIME REFERENCE = 1971




                 START       1000,NP
                 RESET
                 INITIAL     XH1-XH34,0/X105,0/XH102,0
                 INITIAL     X1,0
                 START       500
                 RESET
                 INITIAL     XH1-XH34,0/X105,0/XH102,0
                 INITIAL     X1,0
                 START       500
                 RESET
                 INITIAL     XH1-XH34,0/X105,0/XH102,0
                 INITIAL     X1,0
                 START       500
                 RESET
                 INITIAL     XH1-XH34,0/X105,0/XH102,0
                 INITIAL     X1,0
                 START       500
                 RESET
                 INITIAL     XH1-XH34,0/X105,0/XH102,0
                 INITIAL     X1,0
                 START       500
                 REPORT
                 OUTPUT
                 EJECT
                 GRAPH       TF,TEN6
                 ORIGIN      55,10
                 X           ,1,3,0,1,30
                 Y           0,5,25,2
```

```
54      STATEMENT  58,24,PLOT OF TEN6 FREQUENCIES
        ENDGRAPH
        EJECT
        GRAPH      TF,WRONG
        ORIGIN     55,10
        X          ,1.3,0,1,30
        Y          0,2,50,1
44      STATEMENT  58,44,PLOT OF WRONG DISPATCH DISTANCE DISTRIBUTION
        ENDGRAPH
        END
```

BLOCK NUMBER	SYMBOL	REFERENCES BY CARD NUMBER						
1	CALLS							
102	EAST2							
124	FIELD	398						
139	FINSH	442						
145	FIN01	466						
161	MOVET	507						
163	MOVEV	509	510					
167	MOVEW	513						
172	MOVEY	498	499					
146	MVCR	340						
169	MVCRN	515	516					
149	MVCR1	522						
152	MVCR2	518						
156	MVCR5	501						
157	MVCR6	504						
17	MVRT	524						
136	OLOAD	356						
134	OUT01							
11	RADIO	391						
123	SCAN0	410						
103	SCAN1	345	346	347	348	350	351	352
		353	355	361	362	363	364	366
		367	368	369	371	412		
107	SCAN2	395						
111	SCAN3	399						
120	SCAN4	393	407					
51	SCGD1	349	354					
84	SCGD2	365	370					
96	SCGD3	382						
116	SCN3	402						
114	SCN4	406						
117	SCN8	403	405					
130	TKOFF							
129	TYM03							
10	WEST2							
101	WRAD0	328						
89	XPOS1	375						
178	XXX1	531						
180	XXX2	528						
92	YPOS1	378						
99	ZNFL1							

FACILITY SYMBOLS AND CORRESPONDING NUMBERS

26	ASL1
53	ASL2
80	ASL3
107	ASL4
106	CAR00
1	CAR01
2	CAR02
3	CAR03
4	CAR04
5	CAR05
6	CAR06
7	CAR07
8	CAR08
9	CAR09
10	CAR10
11	CAR11
12	CAR12
13	CAR13
14	CAR14
15	CAR15
16	CAR16
17	CAR17
18	CAR18
19	CAR19
20	CAR20
21	CAR21
22	CAR22
23	CAR23
24	CAR24
25	CAR25
28	CAR26
29	CAR27
30	CAR28
31	CAR29
32	CAR30
33	CAR31
34	CAR32
35	CAR33
36	CAR34
37	CAR35
38	CAR36
39	CAR37
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41	CAR39
42	CAR40
43	CAR41
44	CAR42
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90	CAR84
91	CAR85
92	CAR86
93	CAR87
94	CAR88
95	CAR89
96	CAR90
97	CAR91
98	CAR92
99	CAR93
100	CAR94
101	CAR95
102	CAR96
103	CAR97
104	CAR98
105	CAR99
150	FAST
109	LIEU
110	MCYC1
111	MCYC2
112	MCYC3
113	MCYC4

114	MCYC5
115	MCYC6
116	MCYC7
27	SARG1
54	SARG2
81	SARG3
108	SARG4
149	WEST

STORAGE SYMBOLS AND CORRESPONDING NUMBERS

1 UNITS

QUEUE SYMBOLS AND CORRESPONDING NUMBERS

150	EAST
149	WEST

TABLE SYMBOLS AND CURRESPUNDING NUMBERS

4	FTIME
5	NOSVC
6	TEN4
2	TEN6
7	TEN6
3	WRONG
1	XCESS

FUNCTION SYMBOLS AND CORRESPONDING NUMBERS

7	CALU
3	DISTN
2	EXPON
9	GROW
8	INVU3
4	MAP
5	REMAP
1	SHFT1
6	TRAD

BIBLIOGRAPHY

Gordon, Geoffrey. System Simulation. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1969.

Emshoff, James R.; Sesson, Roger L. Design and Use of Computer Simulation Models. New York, N.Y.: The Macmillan Company, 1970.

Ya-Lun Chou, Statistical Analysis with Business and Economic Applications New York, N.Y.: Holt, Rinehart, Winson, Inc. 1969.

Irwin Miller and John E. Freund, Probability and Statistics for Engineers Englewood Cliff, N.J.: Prentice Hall, 1965.

Mainsell and Gnugnoli, Simulation of Discrete Stochastic Systems, Chicago, Illinois: Science Research Assoc., 1972.

C.W. Churchman, "An Analysis of the Concept of Simulation" Symposium on Simulation Models: Methodology and Applications to the Behavioral Sciences Cincinnati, Ohio Southwestern Publishing Co., 1969.

Martin Phaff and Anita Phaff, "Statistical Analysis of Simulations of Human Systems": Proceedings of Eighth Symposium of the National Gaming Council, Excelsior Springs, Mo., June, 1969.

G.S. Fishman and P.J. Kiviat "The Statistics of Discrete Event Simulation", Simulation, April, 1968.

Richard C. Larson, Urban Police Patrol Analysis: The Massachusetts Institute of Technology Press, 1972.